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The Key to Chronic Fatigue

Does a Fly Know When It's in Control?

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FEATURES

14 **Survival of the Sexiest**

“Survival of the fittest” never applied to beards, so why did they evolve and what role do they play in mate selection in modern society?

17 **Remote Weapons: Ethics from a Distance**

Are military drones that launch lethal attacks by remote control of any more concern than traditional warfare capabilities?

20 **What’s the Key to Chronic Fatigue?**

Chronic fatigue has a range of debilitating symptoms that have defied a pathological explanation. Now researchers are zeroing in on receptors with a role in the immune system.

22 **Does a Fly Know If It’s in Control?**

What do the brain waves of a fly placed in a virtual reality arena tell us about self-awareness in animals?

24 **Off the Grid**

Australians have taken to solar energy, but much of the electricity they generate cannot be stored and is returned back to the grid. However, commercial residential battery systems are now available, with new technologies on the horizon.

27 **A Renewable Solution to the Problem of Peak Power**

Despite the rapid uptake of solar and wind energy worldwide, fossil fuels are still required when the wind doesn’t blow and the sun doesn’t shine. However, a cheap and proven storage option, in combination with wind and solar energy, could replace the need for fossil fuels with 15 years.

30 **This Little Piggie Went Wee Wee Wee**

Microalgae strains that can survive the extreme conditions in piggery effluent could not only clean up the wastewater but also reduce greenhouse emissions, provide a source of biofuel and even be fed back to the pigs.

33 **How to Recruit 23 Million Scientists**

Partnerships between scientists and everyday Australians are changing the face of scientific discovery and exploration.

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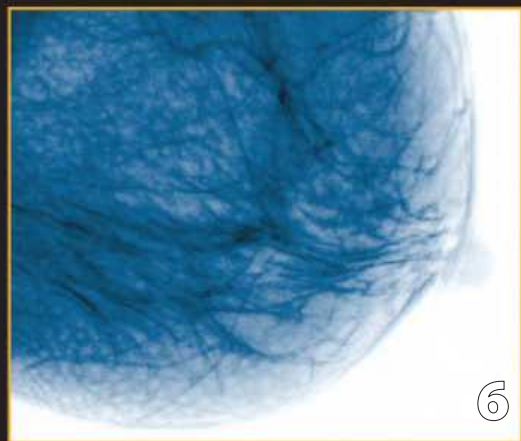
36 **We Will Never Cure Cancer, So Should We Even Try?**

Billions of dollars are spent on cancer research each year for minimal gains. Would that money be better invested elsewhere?

38 **Our Human Right not to Be Poisoned**

Thousands of new chemicals are released each year, and the toxic effects are mounting. What can we do about it?





REGULAR COLUMNS

5 **Simon Says**

A political career is different to any other in the highs and lows it offers, and it almost always ends badly.

6 **Browse**

A round-up of science news from our shores.

40 **Expert Opinion**

Epigenetic differences between male twins has been used to identify sexual orientation with up to 70% accuracy.

41 **Neuropsych**

Is it possible to significantly change a person's beliefs by stimulating the brain?

42 **The Fit**

We're getting healthier and living longer, but the rich more than the poor.

43 **The Fossil File**

Dangerously low levels of trace elements might be implicated in three mass extinctions.

44 **Directions**

Australia can quickly turn our wastewater from a burden to a benefit.

45 **Out of this World**

Pulsar glitches help to weigh a star, and Jupiter's Great Red Spot is shrinking.

46 **The Bitter Pill**

Practitioners of dry-needling swear by it, yet there is no evidence it will relieve your muscular aches and pains.

47 **The Naked Skeptic**

How concerned should we be that only 39% of psychology research can be replicated?

48 **EcoLogic**

Chytrid fungus has devastated many frog species, but there is reason to be hopeful.

49 **Low Tech**

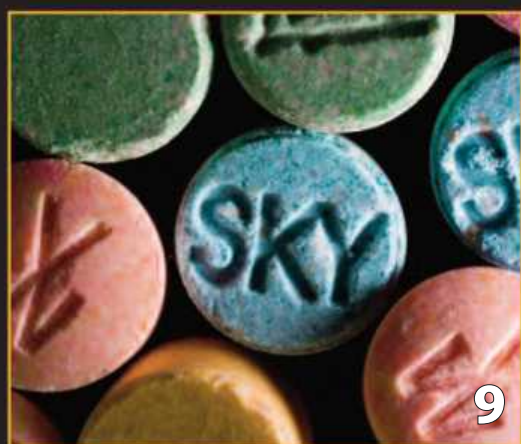
Australia's nuclear waste is being returned from France, and New Zealand is finally reporting on the state of its environment.

50 **Quandary**

Gene editing promises to enable the safe use of pig organs to transplant into humans. Who could object to that?

51 **Australasian Sky**

Your map of the night sky this month.



The Abbot Experiment

A political career is different to any other in the highs and lows it offers, and it almost always ends badly.

One theory affirmed by the failure of Tony Abbot's prime ministership is that all political careers end in failure, a rule affirmed by the fates of predecessors Julia, Kevin, John, Paul, Bob, Malcolm, Gough, Billy, and John. (Bob Brown is the exception that proves it).

Anyone engaged in scientific research knows that more experiments fail than are successful, and you often learn more from the failures than the successes. Abbot's failure is a window into the potential for greatness and desolation in a political life.

Consider the (true) story of a man who boarded a Qantas plane in New York early last year for the haul back to Sydney. After settling into his Economy seat, he received the kind of invitation that can inspire belief in a gratuitously beneficent almighty: "Would you like to move up to Business, sir?".

Padding up the aisle past the luckless 99%, who does he find behind the hallowed drapes but (then) Treasurer Joe Hockey heading for the same seat. Joe was coming down from First because it's a bad look for polities to fly at the front of the plane where the wine is finer and the food diviner.

The stewards deferred to the Treasurer's imperative. But rather than sharing the joy by upgrading a real Business passenger, they ushered our man further forward to

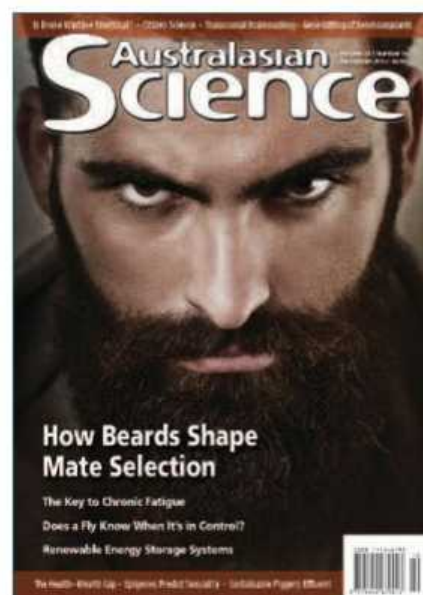
Joe's seat in First. As he looked around he found himself sharing the elite dormitory with (then) Secretary of the Treasury, Martin Parkinson, and Reserve Bank Governor, Glenn Stevens.

They both earned more per year than Hockey, didn't need endorsement from the hoi poloi every 3 years to keep their gig, didn't have to front rabid journos from *Sunrise* to *Lateline*, didn't have to ruin weekends by doorknocking their constituencies... and they fly First with impunity, literally under the media radar.

This contrast between the fates of those who choose a political life and the rest of us occurs at all levels. It's almost 30 years since "new" Parliament House was opened. In that time hundreds of polities have been and gone, while many others who work there - journalists and cleaners, security guards and public servants - have been doing so for the duration.

Perhaps more so than any other, a political career carries the risk of rising too high, beyond your level of competence, something you only discover when you crash. This happened to Abbot and Hockey.

As Opposition leader Abbot's discipline and slogans enabled him to win an election against a messy Labor team, while as Shadow Treasurer Hockey was seen to be a star Coalition performer.



Cover Story

Facial hair has had a resurgence in popularity in recent years. Beards are "in", and men go to great lengths to groom and maintain them. But why do beards exist in the first place, and how do biology and culture interplay to shape their meaning as an animal signal? See page 14.

But it took just 2 years in government for the remorselessly Darwinian system of politics to expose their flaws and shoot them down.

It's a character-building experiment, politics. Good luck, Malcolm.

Simon Grose is Editor of Canberra IQ (canberra.iq.com.au)

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Breast Cancer Starved by Meat and Dairy Nutrient

The discovery of a significant link between breast cancer and nutrition is leading to a new treatment to “starve” breast cancer cells.

A/Prof Jeff Holst’s team at Sydney’s Centenary Institute stopped breast cancer cells from growing by blocking the proteins that pump key nutrients into the tumour cells. The method has now proven to be effective in preventing the growth of melanoma, prostate cancer and breast cancer cells.

The key nutrient of interest in the study, glutamine, is abundant in meat and dairy products. It is also produced naturally in the body, so a change of diet alone is not sufficient to starve the cells. The Centenary Institute is now working on drugs to block the nutrient pumps that allow glutamine to be absorbed by the cancer cells.

Holst said there is strong evidence to support a link between nutrition and cancer, and this new discovery demonstrates a way to tackle it. “African and Asian women have significantly lower rates of breast cancer,” he said. “However, upon moving to western nations and consuming the western diet, rates drastically increase.

“Unlike normal cells, many cancer cells rely on glutamine instead of glucose for the energy they need to divide and grow. We have discovered a way to stop tumours from growing by starving them of this essential nutrient.”

Holst said the research also offers new hope for treating the highly aggressive “triple-negative” subset of breast cancer. “Not only did we find that triple-negative breast cancer cells have more glutamine pumps on their surface, but also that blocking these pumps stopped the tumours from growing.”

The study, conducted in both cell and animal models, has been published in *Oncogene*.

Light Exposure Linked to Weight Gain in Children

Pre-schoolers exposed to more light earlier in the day tend to weigh more, according to research presented to the Sleep Downunder Conference in Melbourne.

Early childhood researchers at Queensland University of Technology studied 48 children aged 3-5 years over a 2-week period, measuring each child’s sleep, activity and light exposure along with their height and weight.

“We found moderate intensity light exposure earlier in the day was associated with increased body mass index, while children who received their biggest dose of light – outdoors and indoors – in the afternoon were slimmer,” said PhD student Cassandra Pattinson.

“Surprisingly, physical activity was not associated with the body mass of the children, but sleep timing and light exposure was. This is the first time light has been shown to contribute to weight in children.

“With an estimated 42 million children around the globe under the age of five being classified as overweight or obese, it is a significant breakthrough and a world-first.

“Thanks to artificial lighting, including light given off by tablets,

mobile phones, night lights and television, modern children are exposed to more environmental light than any previous generation. This increase in light exposure has paralleled global increases in obesity.”

Pattinson said that the timing, intensity and duration of exposure to both artificial and natural light have acute biological effects in mammals. “The circadian clock ... is largely driven by our exposure to light and the timing of when that happens. It impacts on sleep patterns, weight gain or loss, hormonal changes and our mood.

“Recent research in adults suggests exposure to light later in the day is associated with increased body mass, but no studies had investigated these effects in young children and it turns out it has the opposite effect. While adults who take in more morning light are slimmer, pre-school children exposed to morning light tend to be heavier.

“Factors that impact on obesity include calorie intake, decreased physical activity, short sleep duration and variable sleep timing. Now light can be added to the mix.”

Glowing Fingerprints Illuminate Forensic Evidence

By adding a drop of liquid containing crystals to crime scene surfaces, investigators using a UV light will be able to see invisible fingerprints “glow” in about 30 seconds as a result of new CSIRO research. The strong luminescent effect creates greater contrast between the fingerprint and the surface, enabling higher resolution images to be taken for easier and more precise analysis.

CSIRO materials scientist Dr Kang Liang believes that the technique, published in *Advanced Materials*, could be used for more challenging situations where conventional dusting for fingerprints is not appropriate.

“While police and forensics experts use a range of different techniques, sometimes in complex cases evidence needs to be sent off to a lab where heat and vacuum treatment is applied,” Liang said. “Our method reduces these steps, and because it’s done on the spot, a digital device could be used at the scene to capture images of the glowing prints to run through the database in real time.”

The tiny crystals rapidly bind to fingerprint residue, including proteins, peptides, fatty acids and salts, creating an ultrathin coating that’s an exact replica of the pattern. “Because it works at a molecular level it’s very precise and lowers the risk of damaging the print,” Liang said.

CSIRO successfully tested the method on non-porous surfaces,



Different colours can be achieved by altering the chemistry of the solution, as seen here on the blades of two knives. CSIRO

including windows and wine glasses, metal blades and plastic light switches. “As far as we know, it’s the first time that these extremely porous metal organic framework crystals have been researched for forensics,” Laing said.

Metal organic framework crystals are cheap, react quickly and can emit a bright light. The technique also doesn’t create any dust or fumes, reducing waste and the risk of inhalation.

The method could also have other applications in new biomedical devices and drug delivery.

Molecules Inhibit Cancer Metastasis and Multiple Sclerosis

An international team of scientists has identified potential inhibitors of cell membrane proteins involved in the spread of cancer to other parts of the body, and in the progression of autoimmune diseases such as multiple sclerosis.

The newly identified molecules strongly inhibit the action of the two chemokine receptors CXCR4 and ACKR3, which work together to regulate cell migration and are thus important in both cancer metastasis and autoimmune disease. The variant that bound most strongly to the CXCR4 receptor inhibited multiple sclerosis in a laboratory study.

“Scientists around the world are looking for ways of blocking the CXCR4 and ACKR3 receptors as a means of preventing or at least slowing down the cell migration that underlies the progression of these diseases,” says Prof Shaun McColl of the University of Adelaide. “We hope these new molecules will be the basis for the design of new drugs that will interfere with cancer metastasis and

inhibit multiple sclerosis.”

The researchers identified twelve molecules of modified human protein that act against the receptors, four of them very strongly. They generated thousands of modified molecules of these natural human proteins and then screened them for their ability to bind to the target receptors. The method produced inhibitors specific to particular proteins.

“Cancer treatment is at the stage where the aim is to get more specific with treating different cancers so there are fewer side-effects of chemotherapy,” McColl said. “The next stage of this research will be to use molecular modelling to work out exactly where these molecules are binding to the receptors and how they are disrupting their function so they can be further modified for even greater specificity.”

The research has been published in the *Journal of Biological Chemistry*.



3D Cell Growth Opens New Path for Spinal Cord Repair

A novel technique to grow cells in three dimensions, without the traditional restrictions of matrix or scaffolds, has opened a new avenue to repair damaged spinal cords.

Dr James St John of Griffith University's Eskitis Institute for Drug Discovery used floating liquid marbles to enable cells to freely associate and form natural structures just like they would normally within the human body.

"Liquid marbles are a remarkably simple way to culture cells in 3D," St John said. "A droplet of liquid that contains the cells is placed upon a carpet of teflon powder to create a liquid marble which can then be floated on cell culture medium.

"By having an air interface between the liquid marble and the cell culture medium upon which it floats, the liquid marble easily rotates. This allows the cells within the liquid marbles to freely associate to form natural structures without the confines imposed upon them by other 3D-culturing methods.

"Allowing cells to grow in this 3D format dramatically increases their growth and function, and is particularly useful for spinal transplantation repair in which cells are transplanted into the injury site."

The floating liquid marble technique can also be used to grow many other cell types in 3D, and is likely to bring dramatic advances in several biological fields.

The new method, published in *Scientific Reports*, enables transplanted cells to survive and better integrate into the injury site.

High Cancer Rates in Indigenous People of High-Income Countries

Indigenous people in the USA, Canada, Australia and New Zealand have high rates of preventable cancers, including lung and cervical cancer, according to research published in *The Lancet Oncology*.

The most commonly occurring cancers among indigenous men, irrespective of region, were lung, prostate and colorectal cancer. Among indigenous women, breast cancer was the most frequent cancer, followed by lung and colorectal cancer.

Of note were high rates of lung cancer among indigenous men in Australia, New Zealand and Alaska. Observed rates were between 44% (Western Australia) and 155% (New Zealand) higher than those observed in non-indigenous men.

Among women, lung cancer rates were also particularly high in New Zealand Māori (four times the rate observed in non-Māori) and Alaskan natives (60% higher than in white women). The incidence of cervical cancer was higher among indigenous women in most jurisdictions.

In Australia, head and neck cancers rates were up to 91% higher in indigenous men than in their non-indigenous counterparts. They were also three-and-a-half times higher among indigenous women in the Northern Territory and twice as high in Alaskan natives compared with white American women.

Despite this, the overall cancer burden was substantially lower in indigenous populations in the USA (except for women in Alaska), similar or slightly lower in Australia and Canada, and higher in New Zealand compared with their non-indigenous counterparts.

"Lower overall incidence in some countries is the result of a lower incidence of several of the most commonly occurring cancers," explained the study's lead author, Dr Suzanne Moore of the Menzies School of Health Research. "The reasons for this are not well understood, but probably include competing causes of death at an early age (e.g. cardiovascular disease and diabetes) and lower frequency of cancer screening, especially for colorectal and prostate cancers. Other factors such as greater parity, earlier age at first birth and longer breastfeeding times might contribute to the lower risks of breast cancer."

Study co-author Dr Freddie Bray of the International Agency for Research on Cancer added: "Lung cancer was the most commonly occurring cancer among indigenous populations in our study. Smoking – a major risk factor for a number of cancers, including of the lung, oral cavity, head and neck, oesophagus, stomach and cervix – appears to be highly prevalent in indigenous communities in all four countries compared to their non-indigenous counterparts."

Writing in a linked Comment, A/Prof Diana Sarfati and Ms Bridget Robson of Otago University said: "These findings strengthen the argument for a strategic focus on the burden of cancer in indigenous people, the need for better monitoring, and the development of interventions that address the factors that drive cancer inequities".

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Hair Samples Reveal the Effects of Ecstasy Use

Swinburne University researchers have used hair samples to measure levels of stress caused by the party drug ecstasy. Lead researcher Dr Luke Downey looked at cortisol levels found in the hair of light and heavy users of ecstasy and also measured their cognitive performance.

“Cortisol is a stress hormone that we all produce in our bodies, and interestingly it is deposited in our hair. Looking at cortisol in hair is a way for us to see how stressed we’ve been in the past,” Downey said.

Previous studies using saliva samples have shown increased cortisol levels after taking ecstasy, but until now there has been no study that retrospectively measured these effects.

“Hair grows 1 cm per month,” Downey said. “We took 3 cm of hair from the scalp of 51 non-ecstasy users, 27 light ecstasy users and 23 heavy ecstasy users to assess the level of stress on their bodies over a 3-month period.”

The study found increased levels of cortisol in heavy and light users of ecstasy, suggesting they had experienced greater levels of stress over the preceding 3 months. Stress levels of light users of ecstasy were 50% higher than the control group, while the amount of cortisol in heavy ecstasy users was about four times higher than light ecstasy users.

Downey’s team also assessed the memory performance in all three groups and found poorer performance in the ecstasy users.

“In measuring both stress levels and memory performance, what we wanted to know was: does that repeated stress on your body



relate to memory problems? Interestingly, no significant relationship between the memory deficits and levels of stress (indexed by the amount of cortisol) emerged,” Downey said. “This increased experience of stress appears not to be the mechanism that produces the memory deficit.”

Downey is now following up this study by using both hair and saliva samples to quantify the experience of stress in ecstasy users.

The study was published in *Human Psychopharmacology*.

Prefetching to Overcome the Netflix Effect

Australians could soon prefetch data to smooth out internet speed humps caused by internet television services such as Netflix.

“The arrival of Netflix has had a disruptive effect,” said Dr Lawrence Ong of The University of Newcastle. “More than one million users are now subscribed to the service, and some Australian providers have reported up to a 60% increase in data consumption since Netflix was launched. In certain areas the network is really struggling to keep pace with demand.”

Prefetch technology predicts future usage by analysing a user’s recent history. Using this intelligence, it automatically downloads the required content during off-peak hours.

“Just as roads become congested and slow during peak hour travel periods, the internet becomes congested and slow during peak evening usage periods, impacting everyone’s experience,” Ong said. “If we can redirect some of that traffic to off-peak periods we can dramatically reduce usage spikes, improving user experience across the internet broadly.”

As the internet is increasingly required to power more things, the technology could help to address performance issues in the short-term. “Everything from our fridges to light bulbs and personal fitness devices now transmit data over the internet as part of an interconnected Internet of Things,” Ong said. “While these devices



place a comparatively smaller demand on the infrastructure, it signals a growing demand.”

Using information theory and graph theory, Ong is studying the fundamental limits of different prefetching technologies and the benefits they bring to wireless and wired communication systems.



Eels in Knots over Food

The unusual feeding behaviour of moray eels, which includes co-operation with other fish to flush prey from reefs and crawling onto land to scavenge for dead fish, is more extensive than previously thought.

Underwater video captured at Scott Reef near Broome in Western Australia has recorded one moray tying its body into a knot to extract food from a bait bag, while another moray used its tail like a paddle to dislodge the food.

Lead author of the study, PhD student Shanta Barley of The University of Western Australia, said morays have traditionally been observed using knots to compress or break large prey into more manageable sizes, and to anchor food while they consume it. However, the use of a fast-moving knot to dislodge food has

never before been observed, nor have they been seen to use their tails as paddles to exert force on a prey item.

“Our observations suggest that having an eel-like body shape opens the door to unusual and useful feeding techniques unavailable to conventionally shaped fish,” Barley said.

“Like moray eels, a group of subterranean, limbless amphibians known as caecilians are also known to rotate rapidly to twist pieces of flesh off oversized prey. The deep sea hagfish also use knots to pry prey out of burrows on the sea floor.”

Barley said the ability of morays to attack and consume

prey much larger than themselves might explain the significant role of moray eels as a mesopredator in reef systems and the evolution of cooperative hunting partnerships with other large fish-eating species.

“There are questions that remain, such as to what extent can moray eels develop new behaviour when faced with unfamiliar situations, and whether the behaviour is passed on between eels in the same population like ‘songs’ in humpback whales,” Barley said.

“Moray eels are facing growing fishing pressure in certain parts of Indonesia. This is worrying as these predators, like sharks, may play a key role in regulating the abundance and behaviour of fish in coral reefs.”

The research has been published in *Marine Biodiversity* (tinyurl.com/plrr29q).

Coral Buffers Itself from Ocean Acidification

The coral species *Porites cylindrica* has an in-built mechanism that protects it from fluctuations in ocean pH, according to research reported in *Proceedings of the National Academy of Sciences*.

Lead author of the study, Ms Lucy Georgiou of the ARC Centre of Excellence for Coral Reef Studies at The University of Western Australia, said that a reservoir of calcifying fluid allowed the coral to continue growing even under relatively low pH conditions found in Heron Island lagoon. “The regulatory mechanism allows the coral to grow at a relatively constant rate, suggesting it may be more resilient to the effects of ocean acidification than previously thought,” she said.

Ocean acidification is caused by rising carbon dioxide, and is one of the greatest long-term challenges facing the survival of coral reefs.

While the findings are positive, it is not yet known if the adaptation is species-specific and limited to colonies where there is a high fluctuation of ocean pH levels.

“We think it is most likely only typical to coral from reefs such



Carbon-enrichment equipment simulated the impact of ocean acidification in Heron Island lagoon. Credit: Dr David Kline, Scripps Institute

as Heron Island lagoon, where temperature and pH fluctuations vary greatly,” Georgiou said. “The next step in this research is to find out if *Porites cylindrica* colonies from more stable environments also have the ability to adapt and hold up to the threats of ocean acidification.

“We also need to explore whether rising sea temperatures impact their ability to maintain a constant internal pH level.”

Indian Myna Is Spreading Avian Malaria

An invasive bird species is carrying, and potentially spreading, avian malaria throughout its range in eastern Australia, a Griffith University PhD candidate has uncovered.

Nicholas Clark found that up to 40% of Indian mynas in south-east Queensland can carry malaria parasites. While they can't infect humans, the parasites pose a significant threat to native wildlife.

Since mynas carry some malaria strains that are exotic to Australia, the spread of the myna could put native birds such as parrots, magpies and butcher birds at risk.

"Malaria parasites are common in Australian birds, but through the use of genetic techniques I have discovered they are more diverse than originally thought," Clark said.

Some of the malaria parasites found in Australia were probably introduced from other countries and are now being spread by the myna, which was brought to Australia in the 1800s to control insect pests on crops. "These malaria parasites seem to have little effect on the mynas but could be harmful to native birds as they come in contact with each other," Clark said.

"Mynas are known to impact native birds by driving them away from nesting sites, but my work suggests they are also exposing our natives to new diseases."

Clark, whose discovery was published in the *International Journal for Parasitology*, said that avian malaria parasites cannot be spread to people. However, he said that the next step in his research would be to investigate what other diseases invasive birds like the Indian mynas are potentially carrying, and determine if these are a risk to people.



Greener but Drier

Satellite observations published in *Nature Climate Change* have revealed that plants in Australia's semi-arid and subtropical regions are becoming greener because of increased atmospheric carbon dioxide. However, the vigorous growth of plants requires more water, so less run-off now flows into many of Australia's river basins.

"To compound matters, many important regions are projected to experience future declines in rainfall as a result of climate change," said lead author Dr Anna Ukkola, who performed the research at Macquarie University but is now based at the ARC Centre of Excellence for Climate System Science.

"This means water resources for agriculture and environmental flows in places like the Murray-Darling Basin, inland Queensland and south-western Western Australia's wheatbelt will be reduced even further."

But there was also a positive side to the greening. Because plants use water more efficiently where there is more carbon dioxide, less water is required to produce the exact same amount of leafy vegetation under high CO₂ conditions.

The satellite measurements indicated that areas of Australia with sufficient water resources were indeed showing an increase in vegetation. "This increased production is a boon for farmers where water resources are readily available, but the problem is for those

regions that already experience water scarcity on a regular or semi-regular basis and where farmers rely on stream flow for irrigation needs," Ukkola said.

As droughts regularly show us, once rainfall drops below a minimum level, plant growth slows and, if water scarcity is severe enough, they die. "The role of vegetation makes predicting future water resources difficult at best," said co-author Dr Trevor Keenan. "We are, however, getting a better picture of likely possible futures for vegetation, water resources, and the impact of climate change on society in Australia."

As part of gaining a clearer understanding, the researchers quantified the "precipitation threshold" at which there is enough rainfall to maintain a level of plant growth that is not restricted by a lack of water. Interestingly, observations from 1982-2010 show that as atmospheric carbon dioxide has increased over Australia and made plant growth easier, the precipitation threshold has declined.

During this time an average annual rainfall of around 900 mm was required for plants to grow without being restricted by a lack of water. However, the average amount dropped to around 750 mm/year from 2001-08.

"While there are clearly some positives for growth found by this research, it also shows us that some of our crucial agricultural areas will not see these benefits because of the future impacts of climate change on rainfall," Ukkola said.



A broad-lipped bird orchid with its male pollinator.

Size Matters for Sexually Deceptive Orchids

The size and shape of orchids play a major part in an act of deception that entices male wasps to pollinate their flowers, with ecologists at the Australian National University discovering orchids that mimic how female insects look. Until now it had been thought that orchids only produced a scent to mimic the sex pheromones of female insects in order to deceive male insects.

"The orchids exploiting these wasps both have to look good and smell good to ensure that the transfer of pollen is established," said Dr Marinus de Jager, who was a visiting postdoctoral fellow at ANU when he completed the study with Prof Rod Peakall.

Australia is home to most of the world's species of sexually deceptive orchids. These include two different but closely related species of orchid, the broad-lipped bird orchid and the large bird orchid, which are pollinated by two different species of wasp.

Kiwis Value S&T

A New Zealand survey has reported that 90% of respondents believe it's important to study science and technology subjects at school.

The Public Attitudes to Science and Technology survey involved more than 2500 online and 500 telephone interviews, and also found:

- 83% of respondents consider science important for New Zealand's international competitiveness, improving health (91%) and preserving the environment (87%);
- 80% think it is important to be kept up to date on science issues; and
- 82% think that science is important for addressing key challenges affecting society.

The survey was conducted as part of the Science in Society project, an education/science sector collaboration to lift engagement and achievement in science and technology.

Despite their differences, they both produce the same chemical to attract their respective male wasps.

The research found that wasps of both species behave very differently towards each orchid, but in both cases males tried to mate more often and for longer with the orchid they normally pollinate.

Peakall said that shape and size has a dramatic effect on pollinating behaviour. "We can present the chemicals on little black beads and pollinators will come in and attempt to mate," he said. "Without the right shape and size you will get the pollinator to the flower with just smell, but it won't contact the pollen reproductive structures."

de Jager said the research, which has been published in *Functional Ecology* (tinyurl.com/n9grd89), will lead to greater investigation into pollinator behaviour as a driver of floral trait evolution in a diverse range of orchids, both in Australia and internationally.

Orange Peel Mops Up Mercury Pollution

Researchers at Flinders University have successfully created a new material made of industrial waste and unwanted orange peel that can suck mercury contamination out of water.

Mercury pollution occurs as a consequence of a number of industrial activities, including mining and the burning of fossil fuels. Mercury levels in the ocean have tripled since the beginning of the Industrial Revolution.

Mercury exposure - whether through the skin or through the ingestion of contaminated food, such as fish - damages the central nervous system and is particularly dangerous to pregnant women and children. Mercury also compromises the reproductive health of birds and fish.

The plastic-like substance, developed by Dr Justin Chalker of Flinders University, is made entirely from sulfur and limonene, which are waste products of industry and agriculture. Limonene is found mainly in orange peels.

Chalker says that the new polymer is cheap to produce due to the global abundance of waste sulfur and limonene, making it affordable to use in large-scale environmental clean-ups, to coat

water pipes carrying domestic and waste water, and even to remove mercury from large bodies of water.

"More than 70 million tonnes of sulfur is produced each year by the petroleum industry, so there are literally mountains of it lying unused around the globe, while more than 70,000 tonnes of limonene is produced each year by the citrus industry.

"So not only is this new polymer good for solving the problem of mercury pollution, but it also has the added environmental bonus of putting this waste material to good use while converting them into a form that is much easier to store so that once the material is 'full' it can easily be removed and replaced."

Another bonus is that the polymer can remove toxic metals from water, and even in small amounts can be used to detect mercury in areas where pollution is suspected due to a chemical reaction that causes the dark red polymer to turn bright yellow when it absorbs mercury.

The research has been published in *Angewandte Chemie International Edition*.

Celebrity Chef's Bent Spoon

The Australian Skeptics has awarded its 2015 Bent Spoon award to celebrity chef Pete Evans for being the “perpetrator of the most preposterous piece of paranormal or pseudoscientific piffle”.

Evans is a judge on the TV program *My Kitchen Rules* and the promoter of the paleo diet, which promotes the diet available to the Stone Age man.

“It is not only for his diet that he is a worthy winner, even though it can apparently shrink tumours, reduce diabetes, cure autism, stop asthma and reverse chronic fatigue,” said Eran Segev, President of Australian Skeptics Inc. “There are elements of it that are probably useful, although bone broth for babies is a worry.

“No, he has won the award for his support of pseudomedicine, his stance against fluoridation, and his association with rabid anti-vaccinationist Stephen Mercola – ‘the legend’ as Evans calls him.

“Is Evans genuine? I don’t know. Check out the lengthy disclaimer on his Facebook page to see how he protects himself from his own pronouncements. But he is certainly influential, and he has a wide following, so when he pushes something of highly dubious quality or scientific evidence, then it has to be a worry.”



Salt Unbalances the Immune System

Too much salt in food can push the immune system out of balance, according to a new study published in the *Journal of Clinical Investigation*.

A team of researchers led by Dr Katrina Binger of the Baker IDI Heart and Diabetes Institute observed a link between excess salt consumption by rodents and delayed healing of their wounds due to reduced immune cell activity.

Binger's group found that too much salt in food weakens type 2 macrophages, which are the first responders to infection and play a critical role in repairing wounds and combating excessive levels of inflammation. Wound healing was delayed in rodents fed a high-salt diet, in part because of the salt-related weakening of these particular scavenger cells.

At the same time, previous studies by Binger's team have shown that cells that cause inflammation responded positively to a higher salt intake. The overall result of these seemingly contradictory studies is that salt pushes the immune system out of balance by boosting inflammatory cells while inhibiting cells that stop inflammation, such as type 2 macrophages.

“The clinical implications of this research are that eating too much salt doesn't just elevate blood pressure – it compromises the balance of the immune system to directly cause chronic diseases,” Binger said. “Dietary salt restriction is a neglected therapeutic option, which could now be looked at for a number of different diseases, such as type 2 diabetes, rheumatoid arthritis and multiple sclerosis.”

Sensor Protein Tells Cells to Burn Fat

The discovery of a “sensor” protein that instructs cells to burn their fat stores could play a major role in the fight against obesity and metabolic diseases such as type 2 diabetes.

The NLRP1 protein is switched on when increased dietary intake triggers cells to become unstable. Activating the protein sets off a chain of events that instructs cells to use up their energy or fat stores to prevent excess fat from accumulating. “We showed that without NLRP1, fat stores continue to build up, especially with a high-energy diet, leading to obesity,” said Dr Seth Masters from the Walter and Eliza Hall Institute.

NLRP1 is more commonly known for its role in the immune system. “However, it is becoming increasingly clear that immune signalling proteins also have an important role in regulating metabolism,” Masters said.

“This study provides compelling evidence that the immune system is activated not only during infection, but also in response to the loss of metabolic equilibrium associated with a high-energy diet,” said Dr Andrew Murphy of the Baker IDI Heart and Diabetes Institute. “In order to combat the worldwide obesity epidemic it is essential to understand the immune mechanisms the body uses to prevent obesity, insulin resistance and the development of type 2 diabetes.”

The key to NLRP1 and its anti-obesity effects is how it controls an important lipid-regulating hormone called interleukin-18 (IL-18). “We showed for the first time that NLRP1 is the key to IL-18 production, explaining how it acts to reduce obesity,” Murphy said.

“Our long-term goal would be to develop a small molecule that activates the pathway to produce IL-18. In people who are obese, this would help the body to switch on this system and burn existing fat stores.”

However, the investigators cautioned that the treatment would have to be tightly controlled to avoid potential side-effects. “Our research showed that activation of NLRP1 could be exacerbated by some diets, and identified that there is a fine balance between increasing the cell's fat-burning abilities and causing harm,” Masters warned.

“This shows us just how active the pathway is, which is important if you are looking at it in a therapeutic sense. It suggests that treatment would be most safe if given in small doses over a long period of time, which is less likely to have potentially negative consequences.”

The research has been published in *Cell Metabolism*.

Survival of the Sexiest

BARNABY DIXSON & MONICA AWASTHY

"Survival of the fittest" never applied to beards, so why did they evolve and what role do they play in mate selection in modern society?

Facial hair has seen a resurgence in popularity in recent years. Beards are definitely "in", and men go to great lengths to groom and maintain them. In fact, the male grooming industry is estimated at US\$15 billion globally.

But why do beards exist in the first place, and how do biology and culture interplay to shape their meaning as an animal signal?

The Beard as a Badge of Status

Mention the word "evolution" and most people will instantly think about natural selection and survival of the fittest. When we think about the physical traits that were important for ancestral survival, we imagine men who were physically strong hunters who ran fast and provided for their families. Now add to this image a beard and we have the quintessential caveman.

Yet beards don't make you a better hunter, they don't make you stronger and they certainly don't make you faster. So if beards didn't evolve to help us survive, what are they for?

Beards are an important signal of maleness. They first emerge at puberty with the expression of male sex hormones such as testosterone. Beards are only fully developed by young adulthood, slowly emerging in a pattern from the upper lip down to the chin, and eventually connecting to the sides of the jaw.

This occurs precisely at a time when men become interested in attracting a partner, but are doing so in competition with other males around them. This is known as sexual selection, an evolutionary process that explains the persistence of traits that enhance





dominance to the same sex and attractiveness to the opposite sex without necessarily contributing to survival.

Sexual selection involving male–male competition favours characteristics that enhance social dominance and fighting ability. People tend to rate fully bearded men as being 3–5 years older, more masculine, socially dominant and of higher social status. And when a bearded man displays an angry facial expression, other men rate him as more aggressive than when he's clean-shaven.

Classic examples from other species include the large horns on stags and sharp canines in many monkeys. But the human beard does not directly enhance fighting ability. It's not a weapon. Instead it may be used as a badge of status and a signal of status.

In a study of 154 primate species it was found that males with the most elaborate and conspicuous ornamentation tended to live in large social groups with hierarchies (tinyurl.com/primatebadges). These ornaments are used to stand out and signal identity, rank, dominance and attractiveness to others in the group. Think, for example, of the silver crest on a mountain gorilla or the bright red-and-white facial coloration of male mandrills.

The same holds true for humans. In large groups where we're surrounded by strangers, we need a quick, reliable way to evaluate someone's strength and quality. Secondary sexual traits, or those characteristics that give us an advantage in the mating (and dating) game, do just that. And traits such as beards could increase a man's courting potential by enhancing manliness and helping him stick out from the crowd, in essence acting as his badge of status.

To Beard or not to Beard?

The bigger and more crowded your environment is, the more important it becomes to stick out from the crowd. In a global analysis across 37 countries, beards and other styles of facial hair, such as moustaches and goatees, were more common in larger cities where women expressed a strong preference for them. This suggests that large-scale patterns of facial hair grooming in men are likely to be driven by female choice and the need for men to compete with each other for female attention.

But what happens when everyone else catches onto this idea and starts growing a beard? How does a bearded man stay ahead of the mating game?

Looking different and having rare traits has many advantages. In evolutionary biology, this phenomenon is called negative frequency-dependent selection. In guppies, for example, males with the most distinctive and rare colour patterns avoid predation and get more mates. Eventually these rare colour patterns spread and become so ordinary that female guppies are no longer impressed and predators start to notice.

Could the same hold true for facial hair fashion? In experimental trials, women presented with an excess of beards started to rate them as less attractive (tinyurl.com/frequencybeards). On



the flip side, make beards rare and they become intriguing again and more attractive. So as soon as everyone else starts sporting whiskers, the value of your own facial hairstyle could start to diminish.

Are Beards Actually Sexy?

While beards clearly signal age and sexual maturity, female preferences for male facial hair are remarkably mixed. In fact, only a handful of studies have shown that beards increase men's attractiveness, while others have found that women prefer a clean-shaven partner. Recent research using lower doses of facial hair found that around 10 days of beard growth, or "stubble", is considered most attractive (tinyurl.com/10daystubble; tinyurl.com/beardsmating). This suggests that having at least some facial hair can make men sexy because it may be signalling the ability to produce the male hormones required to grow a beard.

Although beards might not immediately make men look more handsome, physical attractiveness is just one component of being a good mate. Humans raise highly dependent offspring in the context of long-term pair bonds, and beards are viewed more

favourably when considering a man's suitability as a long-term partner and parent (tinyurl.com/10daystubble; tinyurl.com/beardsmating).

Bearded men themselves tend to endorse stereotypical gender roles in heterosexual relationships (i.e. men are the "bread winners"). The associations between age, masculinity and social dominance become associated with the ability to provide for a family, making beards more attractive for long-term relationships.

How Culture Influences Grooming

While evolutionary theory can explain why beards exist, culture might influence how we treat them and respond to them.

The human face is important in communication. You can learn a lot about someone's age, gender, personality and emotions simply by looking at their face. Adding a beard can enhance these signals. Yet many men expend considerable effort every day shaving this prominent cue of masculinity off, either partially or entirely.

A man's decision to groom his beard might occur in response to both prevailing preferences and fashions. There are certain times when beards are attractive and others when they are not, so the social context may drive the direction and strength of people's preferences.

For example, the frequency and popularity of facial hairstyles of men photographed in the *London Illustrated News* fluctuated considerably from 1842 to 1972.

Sideburns enjoyed a spike in popularity in 1853, moustaches with sideburns in 1877, full beards were fashionable during 1892 and moustaches were preferred from 1917 to 1919. Patterns in popularity for each of these styles rose gradually over time, peaked and then diminished to be replaced by the rise of a newer style.

Men's responses do not appear to be arbitrary: beards were more popular when men outnumbered women in the available marriage pool. These are exactly the kinds of social conditions that elevate competition for mates. When there is a greater abundance of men, signalling masculinity to other males may enhance attractiveness to women, highlighting how the value of facial hair fluctuates with the mating market.

Maybe beards have seen the best of times and we will see a decline in coming years. Or maybe it's time for sideburns to make a comeback. Either way, facial hair appears to be one of the few human characteristics that has clearly evolved as a conspicuous signal of maleness, but the value of this signal for outcompeting rivals and attracting a mate is far more complex.

Barnaby Dixon is a postdoctoral research fellow at The University of Queensland's, School of Psychology. Monica Awasthy is a postdoctoral researcher at Macquarie University's Department of Biological Sciences.



UAV operators control an MQ-1 Predator from Balad Air Base, Iraq.

US Air Force photo/Master Sgt. Steve Horton

Remote Weapons: Ethics from a Distance

ADAM HENSCHKE

Are military drones that launch lethal attacks by remote control of any more concern than traditional warfare capabilities?

Drones, lethal unmanned air vehicles and robots as part of modern warfare: these sound like the realm of fantasy, but we are facing a revolution in military technologies. Many interested in military ethics are concerned that these technological advances might present some important ethical risk, and so we should reject these sorts of remote weapons.

Is there something ethically special about remote weapons that should cause us to be concerned? There are three points at which we might be facing some particular ethical concerns: that remote weapons are special, secret or ensnaring.

Remote weapons allow the application of lethal force by people who are not in the immediate vicinity of battle. Drones are the most commonly thought of technologies here, in part

because they are the most widely used of these remote-controlled technologies. But drones do not necessarily entail lethal force. While drones like the Reaper Drone sometimes use weapons, the vast majority of drones in military use are used for intelligence, reconnaissance and other support roles. While there may be ethical concerns with standard drones, such as privacy and border security, these seem far less ethically troublesome than death by remote control.

At the other end of the scale are war-robots, fully autonomous weapons systems that are designed to make decisions to kill without human intervention. There are certainly deep ethical issues with this sort of technology – perhaps issues of human life and death shouldn't be left up to artificial intelligence. But lethal use of force by unmanned air vehicles (UAVs) do not fit this description:

humans are still “in the loop” and make the final decision about whether to kill or not.

Two things might make remote weapons ethically special – the fact that they operate at a distance, or the idea that they may be particularly disrespectful to those they kill.

The first issue, distance, gives many people their first sense of moral alarm. There seems something ethically problematic with someone in Nevada launching a missile from a UAV against someone in Afghanistan. The distance between pilot and target is so great, the reasoning goes, that such decisions about killing should not be made.

This argument, however, has very little bite. Since the invention of the bow-and-arrow, we have been killing enemies at a distance. Current warfare is frequently fought at a great distance: planes, submarines and battleships all use weapons that impact the enemy at a substantial distance from those firing the weapons. Moreover, the people operating these weapons will rely on TV screens and tools to receive information about their target, just like the UAV pilot. So, in this regard, UAVs are in no way ethically special compared with non-controversial existing military technologies.

Second is the idea that there is something disrespectful about being killed at a distance. However, this would be the same for any weapon beyond hand-to-hand or close-quarters combat. One thing that may make a UAV pilot distinct from a pilot in actual battle is that the UAV pilot is at very low risk of being harmed. A plane could still be knocked out of the sky, but the UAV pilot might be on the other side of the planet. By being so removed from any risk themselves, they are showing disrespect by not fighting fairly. This is called the “extreme asymmetry objection”: the risk of harm between the target and the pilot is so great that the UAV pilot somehow disrespects his target by killing them in this way.

However, war does not have to be a fair competition. It would be absurd to think that we cannot fight the enemy until we’re sure we have the same number of soldiers, the same weapons and the same strengths.

A range of important ethical criteria must be met for a war to be considered just, but “fairness as equality” is not one of them. War is not a sport, and should not be thought of as such.

Of vital importance is that the ethics and laws of armed conflict still apply to UAV pilots, as with any military action. Should a UAV pilot flout the laws of armed conflict by launching a strike against a group of known civilians, this is unethical and likely to be illegal in exactly the same way as it would be for a fighter pilot. That it happens by remote control is not of special relevance.

Perhaps there is something else that is troubling about the use of UAVs in modern conflict: that the ways in which they are used is secret. The argument is that UAV use ought to be banned not



A fully armed MQ-9 Reaper drone taxis down an Afghanistan runway.

US Air Force/Staff Sgt. Brian Ferguson

because of what they are but because of how they are used. Since we don’t know how they are used, we ought to be very concerned when they are used.

The primary focus of criticism here is the US military’s use of UAVs to kill enemies in Afghanistan, Yemen and other areas of conflict. Targeted lethal strikes by the US military cause a proportionally small number of deaths: most deaths are caused by close air support (CAS), where troops on the ground are fighting in close range to both their enemy and civilians. Most casualties are from strikes called in by ground commanders, who authorise CAS strikes. These are not targeted strikes by the military or the CIA.

While the US military and the CIA both use UAVs, the vast majority of kills by UAVs have been done by the military. When reading figures on UAV strikes and deaths, the military use and CIA use are often conflated. This is important to recognise as the legal oversight of military UAV use is very strict, and is hardly secret: the US army’s targeting process, the ways in which decisions about lethal strikes from UAVs, is outlined in *The Targeting Process: The Official US Army FM 3-60 (FM 6-20-10)*. As this is available to purchase on Amazon, any claims about the secrecy of the military are entirely wrong here.

There is, to be fair, no comparable public access to the manual for the CIA’s targeting process, and ethical concerns remain about how the CIA makes its decisions to use lethal force. Following the controversy over the accidental deaths of US citizen Warren Weinstein and Italian citizen Giovanni Lo Porto, who were believed to have been killed in a CIA-led UAV strike against an Al Qaeda compound in Pakistan in January this year, US President Barack Obama said that he wanted to make the CIA program more transparent. *The Wall Street Journal* and CNN have reported that efforts are being made to shift all lethal UAV use away from



the CIA and to the military, in part because of concerns about oversight of the CIA program.

A further question is whether intelligence agencies should be using lethal force at all. US Senator John McCain, for instance, has said that the use of lethal force should be limited to the military.

What remote weapons point to are deeper ethical questions about the role of organisations, what the military ought to be doing, and what intelligence organisations ought to be doing. Again this is not a special problem for remote weapons: the question is not should organisations like the CIA be permitted to use UAVs for lethal strikes, but should the CIA be permitted to use lethal force at all? Ethical analysis of new technologies often does this – the new use shines a light on existing practices and prompts us to ask a deeper set of questions about what we are already doing.

The final issue is perhaps more speculative, but might have more ethical bite than the first two – that of being ensnared. The concern is that by having remote weapons, a country might find it much easier to decide to go to war, but once in war, finds it very hard to get out. Remote weapons could lower the entry costs, but raise the exit costs. Since the pilots are safe at home, this substantially limits the chance of casualties on our side and makes a war seem easier to win. However, this turns out to be a false economy because, once we are in the war, we find out that we have to invest much more, such as soldiers, support staff and long-term investment to stabilise the region.

In order for this to be a serious ethical concern, three conditions need to be met – that remote weapons do actually make it easy to go to war, that they make it hard to leave, and that by comparison with other methods of warfare, they make it easier to get in but harder to get out.

The idea of ease of entry comes back to the negligible threat faced by UAV pilots. If a war is fought remotely, then one's own soldiers will face very little risk. Such a war can become politically more palatable, or even publicly easy to enter. At the core of this claim is an assumption about the way that remote weapons change the domestic perception of war – that these remote wars pose limited risk to the people fighting. In this way, remote weapons do seem to be relevantly different from other methods of warfare. But this doesn't mean that the war will be easy to win.

As the current crisis in Syria shows, many conflicts are immeasurably complex. Knowing exactly who the enemy is with certainty is very hard but is utterly necessary for a war to be just: one can't simply kill civilians and claim ignorance. UAVs can be very helpful in gathering information, but local knowledge, and a deep and sustained engagement at the ground level is essential.

Furthermore, while bombs and bullets are important aspects of winning wars, much more is needed. Remote weapons are increasingly integrated into military practice, but boots on the ground are still fundamental for winning wars, and long-term stabilisation and peace require much more than weapons – remote or otherwise. Any efforts to sell such wars as easy wins ought to be criticised.

Complicating things further is that enemy perception of UAVs might counteract the aims of stabilisation. Some criticisms of the US UAV program in Afghanistan suggest that the use of lethal UAVs have hardened the enemy's resolve and may prompt locals to participate in conflict. Remote weapons might thus become a tool of enemy recruitment, making it harder to resolve conflicts.

So it seems at least plausible that remote weapons could ensnare people into long, drawn out and highly costly military campaigns and could even help foster enmity among the local population, hardening resolve and acting as part of recruitment drives that feed more locals into the enemy military forces. However, this plausibility is dependent on the perception of UAVs: if a government is actively presenting a decision to go war as low cost and winnable because of remote weapons, they are distorting the reality of warfare.

With these discussions in mind, we can draw the conclusions that the concerns about the "specialness" of remote weapons are unfounded, and that the claims of military secrecy are unwarranted. The role of the CIA is, to be sure, much more ethically problematic, but that concern is not about the use of such remote weapons per se, but about the proper function of military and intelligence organisations. Finally, the idea that UAVs could play a role in drawing countries into wars is possible but dependent on the public's perception of the role of these remote weapons in future wars.

Adam Henschke is an ethicist at the National Security College, the Australian National University. He is co-editing *Binary Bullets: The Ethics of Cyberwarfare* for Oxford University Press (due early 2016) and has a book on the ethics of surveillance under contract to Cambridge University Press.

What's the Key to Chronic Fatigue?

DONALD STAINES & SONYA MARSHALL-GRADISNIK

Chronic fatigue has a range of debilitating symptoms that have defied a pathological explanation. Now researchers are zeroing in on receptors with a role in the immune system.

The term “chronic fatigue syndrome” is a poorly conceived diagnostic term to describe a debilitating and protracted condition. It entails profound fatigue, usually worsened by exertion, and an incapacitating type of brain fog associated with greatly impaired memory, concentration and rational and emotional thought processes. Most who experience it describe it as the worst experience of their life. Many are undiagnosed or disbelieved; a number even suicide.

Currently no confirmatory diagnostic test is available, and diagnosis depends on case definitions that have evolved over time. These definitions classify the experience of the illness in terms of fatigue, memory and concentration disorder, and a variety of other symptoms pertaining to the cardiovascular, gastrointestinal and immunological systems. Almost all bodily systems are affected by this illness.

Detective Work

Interestingly, the illness often follows infection, trauma or another incident. Consequently a psychogenic cause was once postulated, but this has largely been discredited.

While laboratory investigation has been frustratingly short of clear changes in blood or tissue samples, there are exceptions. Our laboratory, and other researchers have consistently found significantly impaired natural killer cell function. This is where our detective work began.

The immune system comprises an ancient or innate immune system as well as a more recently evolved acquired immune system. The innate immune system comprises natural killer cells, macrophages, mast cells and even nitric oxide and carbon monoxide produced by the body. The innate immune system is intended to defeat incoming threats such as infection or trauma and its consequences. This part of the immune system has no memory and relies mostly on directing its toxic effects

at the threat. Clearly, poor control of this system or its protracted effects are debilitating.

The acquired immune system relies on memory and a well organised capacity to respond to a remembered threat. This is a far more adaptable and better targeted part of the immune system than the innate system.

Indeed the principle of vaccination depends on this system remembering specific antigens within B cells and plasma cells and producing antibodies to them. T cells also have a vital role to play, and this system relies on intelligent cross-activation between B cells and T cells.

The Missing Pathology

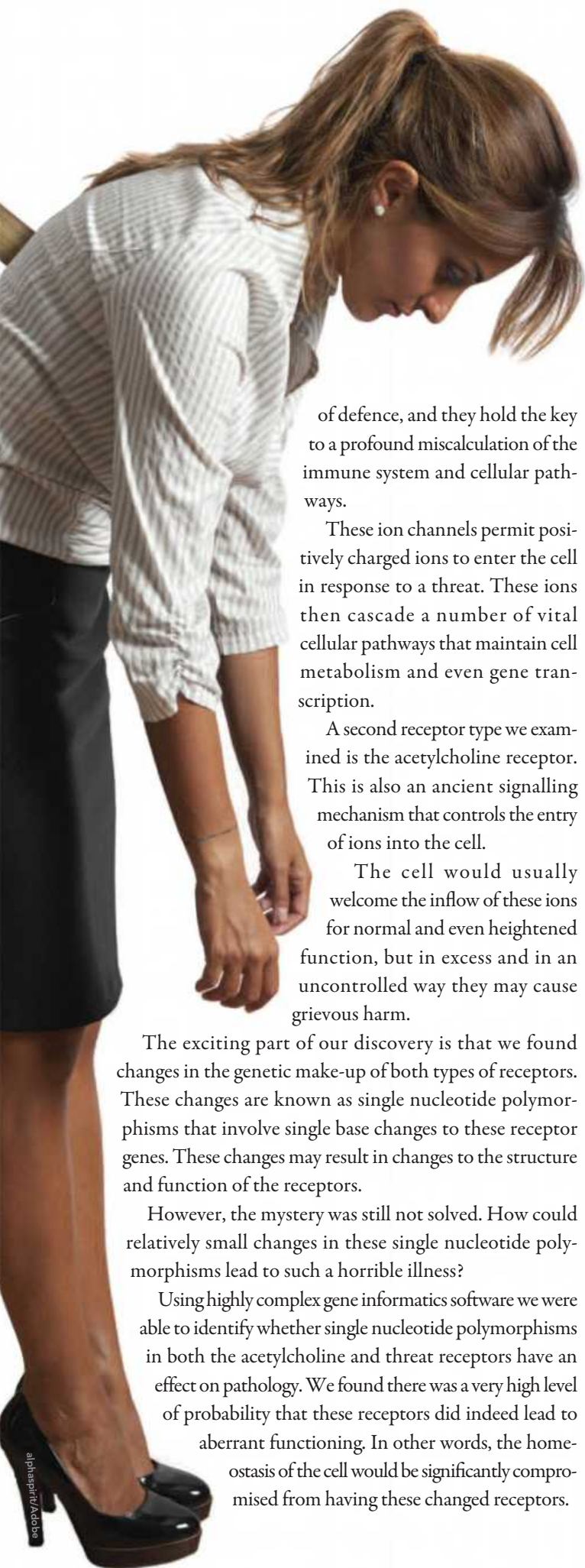
This is where the problem of chronic fatigue syndrome gets interesting. We wondered why patients could be so debilitated and yet so little apparent pathology could be identified.

Much recent work has focused on the acquired immune system. Could the illness be the result of a persistent infection, or could it be an autoimmune process? Could antibodies be identified to aid diagnosis? Could the answer lie in the fact that it was not demonstrable pathology involving changes at the histological level, but rather perturbations or changes in cellular processes critical to homeostasis?

The mystery deepens because various external threats, such as potent chemicals, toxins, tobacco smoke and even some foods, are now known to make the symptoms far worse.

Our research took a different track when we realised that these threats translated into the body in a far more sinister way than was previously recognised. In fact, there are so-called threat receptors located on and in almost every cell of the body. These ion channels are part of the ancient immune system as a first line





The mystery deepens because various external threats, such as potent chemicals, toxins, tobacco smoke and even some foods, are now known to make the symptoms far worse.

of defence, and they hold the key to a profound miscalculation of the immune system and cellular pathways.

These ion channels permit positively charged ions to enter the cell in response to a threat. These ions then cascade a number of vital cellular pathways that maintain cell metabolism and even gene transcription.

A second receptor type we examined is the acetylcholine receptor. This is also an ancient signalling mechanism that controls the entry of ions into the cell.

The cell would usually welcome the inflow of these ions for normal and even heightened function, but in excess and in an uncontrolled way they may cause grievous harm.

The exciting part of our discovery is that we found changes in the genetic make-up of both types of receptors. These changes are known as single nucleotide polymorphisms that involve single base changes to these receptor genes. These changes may result in changes to the structure and function of the receptors.

However, the mystery was still not solved. How could relatively small changes in these single nucleotide polymorphisms lead to such a horrible illness?

Using highly complex gene informatics software we were able to identify whether single nucleotide polymorphisms in both the acetylcholine and threat receptors have an effect on pathology. We found there was a very high level of probability that these receptors did indeed lead to aberrant functioning. In other words, the homeostasis of the cell would be significantly compromised from having these changed receptors.

The Next Steps

We are now focusing on key areas in the cell where these receptors influence cell function and cell products, further explaining this illness and providing insights into other research findings. It is therefore becoming clear that chronic fatigue syndrome is not a simple illness.

Its possible association with the acetylcholine receptor might make it a distant cousin of a debilitating illness known as myasthenia gravis, an autoimmune disease affecting the acetylcholine receptor and one or two others. However, instead of the relatively straightforward pathology of myasthenia gravis, the pathology in chronic fatigue syndrome likely involves genetic changes to the acetylcholine receptor alongside genetic changes to the threat receptors.

A Myriad of Combinations

These changes in both the acetylcholine and threat receptors suggests that this very complex association may develop different combinations of these anomalies and their effects. This is reflected in the varied symptoms reported by chronic fatigue syndrome patients.

Rather than taking a fixed view, we tend to the possibility that across different patients in different populations, and even in the same patients over time, clinical variations may occur due to the different threats that patients encounter. While this may seem contradictory, it suggests that different combinations of altered acetylcholine and threat receptors have varying effects.

Our challenge now is to describe these effects and attempt to unravel the complex pathologies that may cause them through detailed analysis of cellular function and cellular products that are being produced by cells from chronic fatigue syndrome patients and comparing them to healthy people.

If true, these relationships make for a highly complex diagnostic challenge as well as the potential for diverse treatment strategies.

Donald Staines and Sonya Marshall-Gradisnik are co-directors of the National Centre for Neuroimmunology and Emerging Diseases, Griffith University.



Nick Valmas (QBI)

A tethered fly walks on a trackball controlling an object on a digital display, allowing its brain activity to be recorded at the same time. The fly moves the object to the front when it's paying attention to it.

Does a Fly Know If It's in Control?

LEONIE KIRSZENBLAT & BRUNO VAN SWINDEREN

What do the brain waves of a fly placed in a virtual reality arena tell us about self-awareness in animals?

When you step on your car's accelerator, you know that it will go faster. We all know that our actions have consequences, but are animals also self-aware of their actions?

You may find this surprising, but even the tiny fruit fly that hovers around your fruit bowl is calculating her every move. Although her brain is infinitely smaller than a human brain, it is capable of many of the same operations, and may offer some clues to how our own minds work.

Being self-aware and in control of your actions changes how you see and interact with the world. Imagine you are driving to the airport. When you have driven this route several times, you learn how to get there. But if you're always a passenger you may have no idea how to get there if you are suddenly confronted with the task of getting there on your own. This is one example

of how, when you are in control, you pay more attention and learn better than when you are a passive observer.

We know that even insects can learn more efficiently when they learn through their own actions. Yet we still know very little about how our brains might be operating differently when we are in control compared with when we are just observing. This has important implications for learning in the classroom and beyond.

Why would we want to study this in the brain of a fruit fly? Fruit flies have been used in scientific research for more than 100 years, predominantly for genetic studies, and in the past few decades have contributed greatly to the progress of neuroscience. They have much smaller brains than us, containing only 100,000 neurons compared with more than 100 billion in a human brain.

But even though they are relatively simple creatures, they are capable of complex behaviours such as learning, memory and selective attention. To understand these behaviours we can perturb the fly brain in a number of ways that would not be possible in humans.

Since flies cannot tell us what they are paying attention to, we must treat them like human infants, interpreting their behaviours to figure out what they are thinking. This can be done by placing a fly in a virtual reality arena where they can control objects on a screen using their body movements. In the arena, flies can move objects by walking on a ball, similar to how we use a joystick to play a computer game or a steering wheel to drive a car. Flies quickly “understand” that their movements are linked to the virtual objects they see around them, because they adapt their walking behaviour to place objects of interest directly in front of them.

In our study, we let each fly control an object and then we replayed the exact same visual sequence that they were not able to control, thus alternating between control and replay. While the fly was in the virtual reality arena, its brain activity could be recorded by sticking a tiny silicon probe right through the fly’s head to record the electrical signals coming from multiple sites in the brain. The novelty of this type of experiment, aside from the virtual reality environment, was that we could record brain signals across the entire brain, allowing us to examine how the different brain regions interact while the fly was behaving. We hypothesised that there would be differences in brain activity when the fly was in control.

First, we needed to try to understand what the brain of a fly is “seeing” when the fly is paying attention to an object. One way to see how a brain is responding to an object in the environment is to make the virtual object flicker on and off. When an object flickers at a particular frequency, this can be detected in the brain as electrical waves of the same frequency.

In humans, this “frequency tag” in the brain can be used to infer what a person is paying attention to. When you focus your attention on a particular object, the corresponding brain signal gets stronger. This principle can also be used to study what a fly perceives at any given time.

We hypothesised that when the fly was in control of the object, the brain response to the flickering object would be stronger since the fly would be paying more attention to it. Surprisingly, we found that the strength of the fly’s brain response to the object was identical whether it was in control or not. At first we wondered whether this meant that control makes absolutely no difference for a fly; that they are just responding reflexively to changes around them – whether these were caused by them or not.

But when we delved a little deeper by looking at how the different brain regions interact with one another, we found that

when a fly was in control over the object there was increased synchrony between brain regions compared with when it saw the same visual sequence but was not in control. This suggests that the fly may perceive the object differently when it’s in control compared with when it’s experiencing the replayed scenario.

The key difference between these two brain states was reflected in how the brain regions interact. Crucially, we would never have been able to discover this if we had just recorded from one brain region at a time.

The biggest effects we saw were in the centre of the fly’s brain, which is where sensory stimulation from the outside world – such as touch, vision and olfaction – converges, and where flies must make sense of all this information to select the best course of action. It has been likened to the basal ganglia in humans, whose disruption has been associated with loss of movement control in disorders such as Parkinson’s disease, as well as neuropsychiatric disorders that affect attention and goal-directed behaviour.

An important implication of our study is that to understand how the brain produces behaviour in the fly, we need to look at how brain regions communicate, particularly those regions that must coordinate a lot of information. In the real world, when animals adapt their behaviour to achieve a goal they must be able to match their visual perception to their own action. When this cannot be done (as in our replayed scenario), this must be recognised by the animal or else its behaviour may become maladaptive.

In other words, animals need to know when they are *not* in control, such as a fly being buffeted by wind, so that they modify their behaviour to get back in control. In the fruit fly, coordination in the central brain is likely to be crucial for matching sensory feedback to actions, which only occurs when the fly is in control.

In the future, we would like to know more about how the brain coordinates information to produce behaviour. The brain uses a variety of neurotransmitters to transmit signals from one neuron to another. We still don’t know whether particular neurotransmitters could give rise to the sort of brain activity we see when the fly is in control.

We suspect that one neurotransmitter that might be involved is dopamine, which is important for goal-directed behaviour and attention in both humans and flies. The advantage of the fruit fly, *Drosophila*, is that we can ask this question by looking at mutants: what happens to the behaviour and corresponding brain activity in flies that lack certain neurotransmitters, like dopamine, in a virtual reality experiment?

Although the anatomy of the fly brain is very different to ours, understanding how the fly brain operates may help to uncover common principles of attention, self-awareness and learning in humans and other animals.

Leonie Kirszenblat is a PhD student supervised by Bruno van Swinderen at the Queensland Brain Institute, The University of Queensland.



OFF THE GRID

CAMERON SHEARER

Australians have taken to solar energy, but much of the electricity they generate cannot be stored and is returned back to the grid. However, commercial residential battery systems are now available, with new technologies on the horizon.

An increasing number of Australian households now produce their own electricity through rooftop solar panels. During a typical day, the electricity generated will be used to run some appliances, and any power left over is returned to the electricity grid with the homeowner receiving a feed-in tariff for the electricity they return. The plan of the homeowner is for the initial cost of the solar panel installation to be slowly paid back through lower power bills and feed-in tariffs.

The drawback of many renewable energy sources is that the power produced is intermittent and peak energy generation rarely matches peak usage. Solar energy is no different, with peak solar panel output occurring around midday while peak household electricity usage occurs in the evening. This mismatch in peak output and usage would not be a problem if the cost of electricity was equal for both the feed-in tariff and what is charged by the electricity provider.

The recent announcement by Tesla of the Powerwall, a lithium ion-based residential battery storage system, has many people considering going off the grid and relying upon their solar panels to generate their electricity and then storing any excess in their own battery and using it on demand.

Why hasn't this been done before? The answer to this question lies in the technological advancement of the rechargeable battery, their energy-to-weight ratio and their drawbacks.

But the development of rechargeable batteries has progressed rapidly recently due to the demand for light batteries in portable electronic devices such as laptops and phones. This development has focused on increasing the energy-to-weight ratio, with less focus on safety and volume.

This article will review the various battery technologies available for residential energy storage, and review the developments in battery technology that may become available in the future. The average Australian household of four people uses approximately 20 kWh per day, so comparisons will be made for the size and weight of batteries required to produce 20 kWh.

Lead-Acid Batteries

The original rechargeable battery consists of concentrated sulfuric acid as the electrolyte, and lead and lead dioxide on both the anode and cathode. Used in automobiles, caravans and in some electric relay grids, lead-acid batteries have very high recyclability (the number of charge/discharge cycles) and hence have a long lifetime. Slow charge and discharge significantly

reduces the life of lead–acid batteries, and it is often recommended to discharge them to only ~60% of maximum capacity.

Although lead is toxic and sulfuric acid is corrosive, the battery is very robust and rarely presents a hazard to the user. However, hydrogen gas can be produced if the battery becomes overcharged, and this is potentially explosive. With increasing battery size required for residential storage, the amount of each material will increase, as will the hazards. Developments in lead–acid batteries have minimised the loss of the sulfuric acid electrolyte by first sealing the battery and then absorbing the acid into solid materials such as a gel or fibreglass mat.

An example of a commercially available lead–acid battery is Battery Energy’s SG1000. By combining 24 x 2V batteries to create a 48V battery pack (with 100% discharge of 32 kWh), the battery pack is capable of 2300 cycles of 19.2 kWh when discharging to only 60% of its maximum. The entire system would weigh 1296 kg and take up 0.5 m³ in volume (Table 1).

Lithium-Ion Batteries

The current leader in rechargeable batteries is based upon the movement of lithium ions between a porous carbon anode and a lithium–metal oxide cathode. The electrolyte contains some free lithium ions in a liquid electrolyte.

The composition of the cathode has a great effect on the performance and stability of the battery. Currently a lithium–cobalt–oxide cathode has superior charge capacity but is more susceptible to breakdown than lithium–titanate or lithium–iron–phosphate cathodes.

Common breakdown pathways are related to the swelling of the cathode as lithium ions become intercalated within its structure, and the plating of the anode with lithium metal (which can become explosive). The chance of breakdown can be reduced by limiting the charge/discharge rate, but instances of laptop or phone batteries exploding or catching fire are often reported.

The lifetime of the battery also depends heavily on the anode, cathode and electrolyte composition. Generally the lifetimes are superior to lead–acid batteries, with Tesla reporting a lifetime of 15 years (5000 cycles) for the 7 kWh Powerwall when discharged for 5 kWh per cycle. The average four-person house-

hold would need four of these units connected in series (discharging 5 kWh each), and this would weigh 400 kg and take up 0.8m³.

The Tesla Powerwall is the lightest but takes up the most volume of the commercial systems compared in Table 1. The design of the system is visually appealing, and it’s made to be displayed in the home. Tesla has been using lithium-ion batteries in their automobiles for a number of years now, so consumer confidence in their safety is high.

Flow Batteries

An alternative battery architecture is the flow battery. This consists of two storage tanks filled with different electrolytes separated by a membrane that allows the flow of electrons and ions but restricts the mixing of the electrolytes in the storage tanks. Examples of these include vanadium–vanadium, zinc–bromine and bromine–hydrogen.

The electrolytes in flow batteries must have different and stable oxidation states. In a zinc–bromide flow cell, the zinc bromide electrolyte is pumped past two electrode surfaces that are separated by a microporous barrier. During charge, the anode converts zinc ions in solution to zinc metal, which forms a coating on the electrode, while the cation converts bromide ions to bromine. The reverse occurs during discharge.

Flow batteries have very long lifetimes and are very stable. They can be upscaled almost indefinitely but require a pump to cycle the electrolyte around the storage tank.

Redflow’s ZBM2 module has a 10 kWh capacity but is capable of 100% discharge without affecting its performance. Two ZBM2 units are thus required to create a 20 kWh system that weighs 480 kg and takes up 0.55 m³. Redflow gives a warranty of 20,000 kWh, which equates to 2000 cycles.

Many other rechargeable residential power storage systems are currently available. Prospective residential battery purchasers need to consider what suits their environment and budget, and look into all options to find the correct solution. The situation is further complicated by new battery formats under development that could disrupt the battery industry in the future.

Table 1. Comparison of various commercial and future battery systems for residential energy storage.

Battery	Specific Energy (Wh/Kg)	Specific Density (Wh/L)	Mass for 20 kWh (kg)	Volume for 20 kWh (m ³)	Cycles
Battery Energy SG1000 (lead–acid)	15.4	41.0	1296.0	0.5	2300.0
ZBM2 (redox flow battery)	41.7	35.9	480.0	0.6	2000.0
Tesla Powerwall (lithium-ion battery)	50.0	24.8	400.0	0.8	5000.0
Lithium-ion (predicted)	320.0		56.3		
Lithium–sulfur	500.0		36.0		
Lithium–air	1000.0		18.0		
Magnesium-ion	400.0		45.0		

Specific energy is a measure of the energy stored per unit mass, and specific density is the energy stored per unit volume.



Tesla's Powerwall is designed to be a visual feature of the home rather than hidden out of sight. Credit: Tesla

Improvements to Lithium-Ion Batteries

Research labs around the world are working to improve the specific energy, lifetime and safety of lithium-based batteries. Major areas of research include different ratios or chemical structures in the cathode, and the use of graphene and carbon nanotubes in both the cathode and anode.

Graphene and carbon nanotubes have a higher surface area, conductivity and mechanical stability than activated carbon and graphite used in current electrodes. While the exact composition of most anodes and cathodes is currently a trade secret, commercial production levels of carbon nanotubes hint that most phone and laptop batteries already have carbon nanotubes as part of their electrodes.

Carbon nanotubes and graphene can be used as scaffolds to hold active nanoparticles on either electrode. The small size of the nanoparticles will allow faster intercalation and de-intercalation of lithium-ions during charge/discharge, while the carbon nanomaterials provide a fast pathway for electrons to migrate to the nanoparticles.

Lab-based batteries have shown incredibly storage capacity, but often the materials used are expensive or the process used

is difficult to scale to industrial processes. With further reductions in material costs and further simplification of synthesis there is no doubt that the application of nanomaterials will continue to improve the capacity, lifetime and safety of lithium-based batteries.

Lithium-Air and Lithium-Sulfur

Lithium-sulfur and lithium-air batteries are alternative designs with a similar underlying principle of lithium-ion movement between two electrodes with much higher theoretical capacities. In both cases the anode is a thin sliver of lithium while the cathode is Li_2O_2 in contact with either air (in lithium-air batteries) or active sulfur (in lithium-sulfur batteries).

Since the anode in these batteries is lithium metal, the amount of lithium metal required for a residential-scale 20 kWh battery pack (total weight of 18 kg and 36 kg for lithium-air and lithium-sulfur, respectively) may limit their use to smaller devices in the short-medium term.

Sodium-Ion, Magnesium-Ion and Aluminium-Ion

Lithium has an atomic number of 3 and sits in the first row of the periodic table. Directly below it is sodium (atomic number 11).

Sodium-ion batteries are viable alternatives to lithium-ion due to the relative abundance of sodium. The cathode consists of a sodium-metal oxide (e.g. sodium-iron-phosphate) while the anode is porous carbon. Due to the size of sodium ions, graphite cannot be used in the anode so carbon nanotubes and graphene are being developed as anode materials. Since the mass of sodium is greater than lithium, the charge capacity per unit mass is generally lower.

Magnesium sits to the right of sodium on the periodic table (atomic number 12), which means it can exist in solution as Mg^{2+} (compared with Li^+ and Na^+). With double the charge, magnesium is capable of producing twice the electrical energy for a similar volume. However, the double charge makes Mg^{2+} more sluggish as it moves through the electrolyte, slowing the charge rate.

What's Next?

In the short term it's expected that lithium-ion batteries will continue to be improved. Future technologies have the capability to deliver higher specific energy and/or energy density but are expected to enter the market in smaller devices before moving toward residential energy storage.

In the meantime, older technologies such as lead-acid and flow batteries are available with commercial products that exhibit similar performance to lithium-ion and are expected to remain competitive in the short term.

Cameron Shearer is a Research Associate at Flinders University's Centre for Nanoscale Science and Technology.



A Renewable Solution to the Problem of Peak Power

ANDREW BLAKERS

Despite the rapid uptake of solar and wind energy worldwide, fossil fuels are still required when the wind doesn't blow and the sun doesn't shine. However, a cheap and proven storage option, in combination with wind and solar energy, could replace the need for fossil fuels with 15 years.

A renewable energy revolution is in progress, driven by rapidly decreasing prices. Together, new photovoltaic (PV) and wind electricity generation capacity is being installed at a greater rate worldwide than the combined amount of new coal, gas, oil and nuclear (Fig. 1). Within a few years, new PV and wind generation capacity installed each year worldwide may each be larger than the rest of the electricity generation industry combined.

PV and wind constitute nearly all new generation capacity in Australia. Tasmania obtains all of its electricity from hydro and wind. South Australia obtains 40% of its electricity from wind and PV, and this figure will be above 50% by 2020. The ACT will source all of its electricity from wind and PV by 2025.

Figure 2 shows the retirement schedule for Australia's fleet of coal-fired power stations, assuming a 50-year service life. PV and wind can be installed at a sufficient rate to yield a largely renewable Australian electricity system by 2030, smoothly replacing existing coal and gas generators as they reach the end of their working lives.

Solar and wind resources are much larger than all other available energy resources combined. PV and wind systems utilise very common materials, have minimal security and military risks, are available nearly everywhere in vast quantities, and have minimal environmental impact over unlimited time scales.

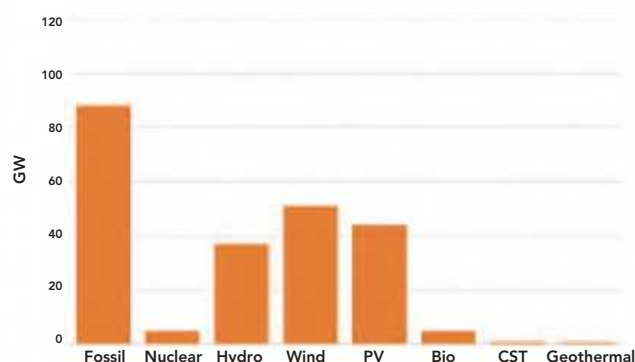


Figure 1. New generation capacity added globally in 2014 by technology type. In 2014, 95 GW of new wind and PV was deployed, together with an additional 8 GW of other renewables (excluding large hydro).

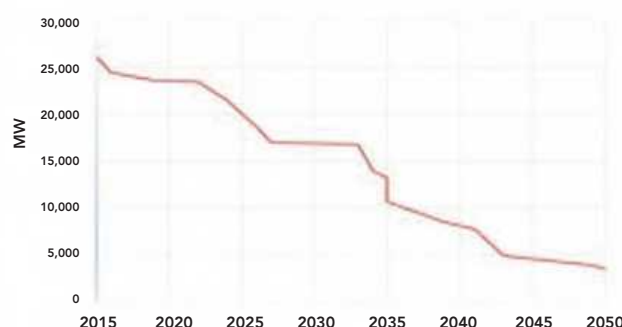


Figure 2. Retirement schedule of Australian coal-fired capacity assuming a 50-year service life.

However, the sun and wind are variable energy sources. When PV and wind constitute more than about half of electricity generation, storage is needed to provide a reliable electricity supply.

Pumped Hydroelectric Energy Storage

Pumped hydroelectric energy storage (PHES) involves pumping water to an upper reservoir when energy is plentiful and cheap. During periods of peak demand, when energy is expensive, water is released through a turbine to recover electrical energy. About 80% of the electricity used to pump the water uphill is recovered, and 20% is lost.

PHES constitutes 99% of energy storage worldwide (>160 GW) because it is much cheaper than alternatives such as batteries. In Australia, existing PHES systems include the Tumut 3, Wivenhoe and Shoalhaven power stations.

PHES is an ideal method of storage: response time (from off to fully-on) is less than a minute, the operational lifetime is 50–100 years, operational costs are low, losses are modest, and PHES provides “spinning reserve” and “black start” capability to help with grid management.

Short-Term Storage

A key point in relation to energy storage in a grid dominated by PV and wind generation is that a few hours of energy storage is usually sufficient. Short-term storage covers high-demand events such as hot summer afternoons and cold winter mornings and evenings, covers peak usage at night, offsets periods of low supply such as wind lulls and cloud, offsets plant and transmission line failures, and covers the time required to bring a low duty cycle biomass-fired power station online or implement demand management if the supply shortfall is likely to be extended. Short-term storage also improves the load factor of constrained power lines, overcoming the need to duplicate powerlines that connect the national grid to wind and solar farms in rural regions.

Currently, traditional hydroelectric and low-duty cycle gas power stations balance any discrepancies between energy demand and supply. As PV and wind energy capacity increases, PHES will increasingly take on this role, supplemented by the use of low duty cycle biomass and demand management to meet occasional shortfalls.

Away from Rivers

Conventional hydroelectric systems are located in river valleys, requiring lake systems spanning thousands of hectares along with expensive and extensive flood control measures to cope with once-in-1000-year floods. As many of the existing hydroelectric power stations are in mountainous national parks, new river-based PHES proposals in these areas would draw strong public resistance to both reservoir construction and extended powerline easements. However, PHES located away from rivers offers low-cost short-



Figure 3. A Google Earth synthetic image of the Tumut 3 power station in Kosciusko National Park (vertical scale exaggerated).

term storage, avoids community conflict, reduces transmission costs, and has an unlimited number of potential sites.

Off-river PHES takes advantage of the vastly larger area of land available beyond river systems, with many good sites existing near roads and transmission powerlines. Off-river PHES comprises pairs of small, hectare-scale “turkey nest” reservoirs whose walls are made from spoil scooped from the centre. The two reservoirs are connected by pipes (or tunnels) that incorporate a pump or turbine. There is no river and no need for expensive flood control.

Essentially, the reservoirs are “oversized farm dams”. They can be located in hilly farming country near roads and power transmission networks. In contrast to standard hydroelectric systems, in an off-river PHES system the same water circulates indefinitely between the upper and lower reservoirs, thus eliminating the need for a river.

Importantly, the upper reservoir in an off-river PHES can be on top of a hill rather than in a river valley, allowing a much larger “head” (height difference) between the reservoirs. This is an advantage since both energy storage capacity and power capacity are proportional to the head, so the energy storage cost scales inversely with the head.

Figure 3 shows a Google Earth synthetic image of the Tumut 3 pumped hydroelectric system located in a deep river valley. Extensive flood control measures have been constructed. The upper reservoir (Talbingo) has an area of almost 2000 hectares, and the head between it and the lower reservoir (Jounama) is 151 metres. Water can be pumped to the upper reservoir for energy storage and returned to the lower reservoir for power generation at a later time.

Now consider a hypothetical off-river PHES system using a pipe running along a powerline easement indicated by the red line. The head is 700 metres, nearly five times larger than for Tumut 3, and there is no need for flood control. Such a system could operate at the same power rating as Tumut 3 (1500 MW) for 4 hours utilising twin 20-hectare reservoirs – each just 1% of the area of Talbingo. Alternatively, it could operate for 24 hours at 250 MW output.



Figure 4. A Google Earth synthetic image of hills east of Whyalla with up to a 600-metre head (vertical scale exaggerated).

Where Could Off-River PHES Be Located?

There are thousands of potential off-river PHES sites outside national park sites along the Great Dividing Range, and also in many other hilly regions. Google Earth is an interesting way you can find off-river sites in your local area (Fig. 4). You should look for sites outside national parks with a head of 200 metres or more (300–800 metres would be better), with steep and short pipes (preferably with a slope of more than 150 metres/km), and within 20 km of a high voltage powerline. Wind farms are often located in hilly farmland close to suitable sites.

Remarkably, many studies of storage opportunities overlook PHES in the mistaken belief that there are few remaining development opportunities. This is due to mistakenly overlooking the very large areas available in off-river sites. Recent comments have included “Australia is flat and arid and has little potential for more hydro”, “Pumped hydroelectric storage is at a mature stage of development, but there are limited locations where these facilities can be built” and “further deployment of pumped hydro is severely limited by geographical and environmental site requirements as well as project size requirements to achieve economies of scale”.

Old mining sites can also be suitable for PHES. For example, Genex Power has proposed a 330 MW PHES system at an old gold mine at Kidston in northern Queensland (Fig. 5). The difference in water level between adjacent pits is about 200 metres.

Indicative Cost

Reductions in PV costs have seen the installation of 1.5 million rooftop systems, and much attention has been paid to the need for batteries to store the excess energy that is returned to the grid. Since PV and PV/battery systems operate “behind the meter” in competition with relatively high retail tariffs, even expensive residential battery units have a large potential market.

However, high penetration of wind and solar energy will be facilitated by low-cost mass storage in the wholesale market, in conjunction with load management. This is where off-river PHES has a key role to play.



Figure 5. Genex Power's proposed Kidston PHES system, an old gold mine in northern Queensland, has a 200-metre head.

Most of the costs of off-river and conventional (on-river) PHES are similar. The main difference is that off-river PHES uses relatively tiny and inexpensive reservoirs that have a much larger head and do not require expensive flood control measures. The costs of off-river PHES systems are relatively predictable because each off-river PHES site looks much like another, whereas river valleys vary greatly. The power costs – pipe, pump, turbine, generator, transformer, control and transmission – comprise most of the expense. The energy cost – the reservoirs – is relatively small.

The indicative costs of off-river PHES are \$1 million per MW, translating to \$20–30 per MWh of storage. This is much cheaper than batteries (around \$200 per MWh).

Environmental and Water Issues

The environmental impact of off-river PHES systems is minor because the reservoirs are small and located outside national parks and sensitive areas. The area of reservoirs required for a 100% renewable energy Australian electricity grid is a few thousand hectares distributed across the country. For comparison, the area of Lake Eucumbene in the Snowy Mountains is 14,500 hectares.

Sourcing of water is a significant but not major consideration in site selection. The ongoing water requirement is equal to evaporation minus rainfall. Calculations show that this is a tiny fraction of the water annually traded in Australia, even if off-river PHES is used extensively, and is a tiny fraction of what is required to operate the cooling towers of a coal-fired power station with comparable power output.

Conclusion

Pumped hydroelectric energy storage constitutes 99% of all energy storage around the world because it is cheap compared with alternatives such as batteries. It is likely to continue its dominance in the wholesale storage market. Off-river PHES can facilitate very high (50–90%) penetration of wind and PV at modest cost through the provision of low-cost, short-term mass-storage of energy.

Andrew Blakers is Professor of Engineering at the Australian National University, specialising in photovoltaics and renewable energy integration.

THIS LITTLE PIGGIE WENT Wee Wee Wee

JEREMY AYRE & NAVID MOHEIMANI

Microalgae strains that can survive the extreme conditions in piggery effluent could not only clean up the wastewater but also reduce greenhouse emissions, provide a source of biofuel and even be fed back to the pigs.

Pork is the most highly consumed animal meat globally, with the pig population currently numbering around 900 million worldwide. Australia has roughly one pig for every ten citizens, so pig production here requires significant effort to keep environmental impacts in check while remaining economically viable.

Wastewater management is one of the important challenges. Piggeries are quite good at isolating their wastewater to prevent the contamination of nearby streams and groundwater, and this seems to be a proven part of the environmental strategy. The wastewater holding ponds utilised by piggeries also provide a treatment that involves anaerobic digestion of the waste to reduce the nutrient load and make the wastewater more manageable.

Pig producers are also moving toward covered ponds that can capture the methane produced and substantially reduce the associated odour. The methane can be a useful on-farm biofuel, and also allows for a reduction of greenhouse gas emissions as the carbon dioxide output from combusted methane is a comparatively less potent greenhouse gas.

Unfortunately there is still no economical and widely used option for treating the anaerobic digestate of the wastewater, apart from evaporative ponds that essentially allow the water to become lost into the atmosphere. This obviously doesn't allow for very effective water recycling. This might offer some degree of water reuse if the water was clean enough to wash down the holding pens and help keep the piggery clean, but the high ammonia content of the anaerobic digestate prevents this. Obviously the more purified the water quality, the more diverse range of uses that are available.

While piggeries are doing the right thing by keeping the greenhouse gas emissions low and preventing water contamination, they are still missing out on the benefits of water reuse and have the additional problem of a very high nutrient load in the wastewater. The piggery anaerobic digestion effluent is therefore an interesting target for novel wastewater treatment technologies.

For some decades researchers have looked at treating the piggery wastewater with microalgae, but the research has been limited to tentative approaches using diluted raw wastewater or sometimes diluted anaerobic digestate. Some approaches have also looked at seawater enriched with the nutrient-heavy wastewater. These approaches relying on dilution are all based on the assumption that the high ammonia content along with the wastewater's very dark colour (due to turbidity) make the medium highly toxic and almost impossible for algal growth.

So far these approaches haven't brought about a change in the technology adopted by the pig industry. In most cases, particularly in Australia, dilution of the wastewater isn't a viable option on a large scale.

Our research is attempting to utilise the wastewater as a beneficial resource rather than a burden. We have also isolated some microalgae species that can treat the undiluted anaerobic digestate of the wastewater.

The high nutrient load in the anaerobic digestate of piggery effluent makes it an interesting growth media for microalgae. Most microalgae cultivation methods depend on external sources of the critical nutrients such as nitrogen and phosphorous, but these nutrients levels are so high in piggery effluent that they are essentially toxic to most living things. Any microalgae capable of acclimatising to these conditions should



dusanpetkovic1/Adobe

therefore have a great advantage in being able to utilise extremely high nutrient levels as fuel for growth. If the issue of the turbidity can be overcome this also clears the way for growth in a very nutrient-rich growth media.

Our team is ramping up its research into the growth of highly acclimatised microalgae on undiluted anaerobic digestate. We have been able to isolate suitable microalgae from a wide variety of sources, such as an experimental piggery south of Perth that had microalgae growing in its evaporative wastewater ponds. By taking samples from this source and others we were able to obtain a handful of strains that can survive on the wastewater. In this case the only treatment prior to microalgae culture was a simple sand filtration process to remove suspended particles from the wastewater.

Following the successful cultivation at a base ammonia level of 700–1000 mg ammonia nitrogen per litre, we were able to demonstrate successful growth up to 1600 mg using synthetically added ammonia. This trial indicates that the microalgae can survive and grow at extremely high ammonia levels. No previous literature indicates growth at such high levels of ammonia.

Now that this groundwork has been laid, the mixed culture system can be optimised further. In a stepwise fashion we can start at the extreme top end of the conditions found in the anaerobic digestate and work towards understanding the limits to growth and economic barriers that might be associated with using the technology at the scale required in real-world piggeries.

Due to the extreme levels of nitrogen and phosphorous, we expect that other nutrients might be in limited supply and therefore need to be added to enhance growth. Control of the pH and the addition of carbon dioxide to the media also allow for some interesting tinkering with the system.

It's certainly possible that the next generation piggery system will use anaerobic digestion to produce a significant biofuel in the form of methane-rich biogas. Indeed, piggeries are already putting these systems in place throughout Australia and other countries.

This also means that the CO₂ output from biofuel combustion can serve as a pH control and additional carbon source to enrich the microalgae culture. Lowering the pH of the culture should lower the ammonia toxicity while at the same time giving the microalgae a boost of carbon.



Dr Navid Moheimani is involved in an array of applied algae projects at Murdoch University, several focusing on novel treatments for anaerobic digestion effluent at piggeries.

We are also looking at different operating conditions, such as variations in pond depth and different bioreactor designs. Algae-harvesting might also play a role in maintaining a productive cell density.

Uses for the end-product algal biomass are also being investigated. A tantalising prospect is to consider using the algal biomass as a protein-rich feed supplement for pig production. Questions to address include any pathogenic properties of the algal biomass and whether the nutritional profile is favourable for pork production.

Another option being investigated with researchers at the University of Western Australia is the prospect of using the algal biomass to boost the methane output from anaerobic digestion. This would allow the algal biomass to feed additional

carbon into the methane production system and improve biogas yields. Increasing interest in biofuels and decentralised energy production systems make this option economically compelling for piggeries.

However, these conditions are likely to produce tough algae, so these options may need a further process to physically break the tough cell wall to allow digestion, either in the gut of live-stock or bacterial reactors.

With any luck the project will bring aspects of the technology closer to application for Australian pig production. We have excellent solar radiation in much of Australia, but the shortage of fresh water restricts the options available to dilute the microalgae culture in an anaerobic digestate production system. A preliminary economic assessment of all of the compo-

nents still needs to take place to determine the technology's overall viability.

Other anaerobic digestate treatments being investigated at Murdoch University are focusing on symbiotic associations between wetland plants and microalgae, comparing nutrient removal between open ponds and closed photobioreactors and comparing the effects on microalgae growth of paddle wheels and jets. Bioprospecting of microalgae is also being performed.


The research has international relevance due to the large scale of pig production globally, and has the potential to improve the economics of pig and other livestock production systems.

Jeremy Ayre is a PhD student supervised by Navid Moheimani at Murdoch University's Algae R&D Centre.

A gift that will be valued through to next Christmas

Dear Santa,
I have been
very good.

Australasian
Science



The Great Koala Count (koalacount.ala.org.au) has harnessed the power of smartphones to capture sightings of koalas in the wild. Koala populations were mapped with the data collected in order to inform important decisions around the management of this iconic species.

How to Recruit 23 Million Scientists

Philip Roetman

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Partnerships between scientists and everyday Australians are changing the face of scientific discovery and exploration.

David Attenborough is talking about it, Brian Cox is talking about it, and it's being talked about all across Australia. Citizen science, the process of engaging the public in scientific enquiry, has undergone a renaissance in recent times and is playing a critical role in re-engaging society in the sciences.

The potential for citizen science to unlock public interest in science in Australia is huge. Already there are more than 130,000 Australians active in at least 170 citizen science projects, with the number and scope of projects rapidly increasing.

Citizen science cuts across scientific fields, institutions, governments and demographics. Projects are run by non-Governmental organisations and community groups, as well as organisations like CSIRO, state governments, private foundations, museums and universities – all unlocking Australia's science potential.

Participation in citizen science has been shown to address environmental issues at many scales, contribute to novel scien-

tific research, improve the skills and knowledge of individuals, increase social networks, and give a voice to underserved individuals and communities.

So how do we harness 23 million Australian brains for exploration and discovery?

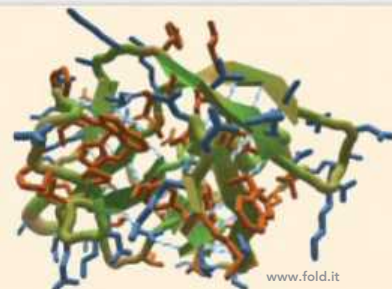
Every Australian can participate in activities like counting koalas while bushwalking, reporting unexpected catches on their weekend fishing trips, or classifying distant galaxies on their home computers. Contributions like these have informed conservation strategies, discovered new animal species, played a role in breakthroughs on debilitating diseases, contributed to global weather forecasting and helped to unlock the secrets of the universe.

Technology, especially mobile phones, has aided the renaissance in citizen science, greatly facilitating the collection of scientific data for a wide range of projects with an accuracy and precision not previously possible.

The result of citizen science is often a large number of scientific records that would be virtually impossible to achieve for a

FOLDIT

Foldit (www.fold.it) attempts to apply the human brain's amazing puzzle-cracking abilities to help predict protein structure. Knowing the structure of proteins is the key to targeting and eradicating certain diseases and creating biological innovations. Rather than just building a useful science tool, Foldit's developers built in gaming elements, using competition as a motivator for citizen scientists to participate.



REDMAP AUSTRALIA

Unusual sightings of marine species are recorded and mapped through Redmap (Range Extension Database and Mapping), an online interactive project and smartphone app (www.redmap.org.au). Data contributed from recreational fishers, divers and beachcombers are used to identify and map which marine species may be shifting in response to changes in the marine environment, such as ocean warming.



WEATHER ON WEB

Collaborations between meteorological agencies such as Australia's Bureau of Meteorology and the UK's National Weather Service (www.bom-wow.metoffice.gov.uk/) has enabled an online infrastructure where citizen scientists can lodge and share weather information and observations. The project provides a cost-effective and well-structured system for collecting a high density meteorological data set beyond the capacity of the Bureau.



small team of scientists, let alone a single scientist. For example, since 1998, 10,000 registered bird observers have contributed 10 million records towards the *Atlas of Australian Birds* database. More recently, through the National Science Week program Explore the Seafloor, close to 10,000 citizen scientists successfully analysed 330,526 photos of marine habitat within a 1-week period.

Despite a huge body of work documenting the value and quality of the data produced by these so-called amateurs, a perception persists among some professionals that the quality of data is insufficient for most research or decision-making purposes. However, a number of rigorous studies have found that citizen science-collected data are robust and useful for the intended purpose. For example, observations by thousands of enthusiastic birders every year are showing patterns of change in the composition of bird communities across Australia and in other countries. Some of our strongest conclusions about the impacts of climate change on natural ecosystems comes from citizen science data.

There are, however, some caveats that accompany the activation of a network of citizen scientists. Although citizen scientists are capable and willing, they require direction and training and obviously should not be exploited. Participants in projects also require support and motivation to continue their involvement. Although they are often already knowledgeable, they benefit from professional expertise and knowledge to grow their capacity in scientific methods.

One promising development for assisting partnerships between scientists and communities is the recent establishment of the Australian Citizen Science Association, a national community of practice for all types of citizen science within Australia. Equivalent national bodies have already been established in the US and in Europe, and collectively these associations are playing a leading role in coordinating the incredible global growth of citizen science. An inaugural national citizen science conference, held in July this year, received support from the Office of the Chief Scientist and the Academy of Science, demonstrating the high level support and interest in citizen science in Australia.

A report commissioned by the Chief Scientist this year suggests that facilitating the growth of citizen science should focus on:

DISCOVERING SPECIES

Stuart Harris did not expect to discover a new spider species when he was out enjoying a weekend bush bash. Posting a photograph online of the unusually coloured peacock spider (*Maratus harrisi*) was the beginning of a new career for this unassuming citizen scientist. The story of his discovery and the epic 3-year quest to re-find the spider inspired a documentary called *Maratus* (<http://tinyurl.com/qhr6twx>) that recently won the Audience Award at the Stronger Than Fiction documentary film festival. To share your nature observations like Stuart see <http://tinyurl.com/okq8tr3> or <http://tinyurl.com/ispotnature>



Some of our strongest conclusions about the impacts of climate change on natural ecosystems comes from citizen science data.

- training and the development of standards, so that individuals and organisations have a greater capacity to deliver best-practice citizen science, and provide scientist and participants with guidance on appropriate question selection, project design, methods of volunteer recruitment and engagement, techniques for data capture and analysis, safe practice in the field, communication with community leaders, and project evaluation;
- improving communication among citizen science projects, host organisations, practitioners and volunteers to limit unnecessary duplication of projects and harness resources more efficiently, particularly within similar organisations such as park agencies, environmental protection authorities, regional and national resource management bodies and local councils. Similarly, a national register of projects (e.g. www.citsci.org or www.scistarter.com) would provide a connecting service to help prospective volunteers discover nearby projects, match scientists to communities, identify data “black spots”, and provide support and training; and
- developing forums for connecting scientists, educators, government, private industry and the community so that interested parties can connect and work together and address issues of local, state, national and/or global importance.

GALAXYZOO

Roughly 100 billion galaxies are scattered throughout our observable universe, each a glorious system that might contain billions of stars. Many are remarkably beautiful, and the aim of Galaxy Zoo (www.galaxyzoo.org) is to study them, assisting astronomers in attempting to understand how the galaxies we see around us formed and what their stories can tell us about the past, present and future of our universe as a whole. Like Redmap and The Great Koala Count, GalaxyZoo relies on the power of multiple observers in order to uncover hidden secrets. The success of Galaxy Zoo has spawned a multitude of other citizen science projects, such as www.zooniverse.org.



The increasing quality, affordability and accessibility of citizen science projects is making it easier to realise the potential for all Australians to contribute to science as part of their everyday lives. Hundreds of thousands of Australians are already tapping into the benefits of this partnership, every one of them pushing the boundaries of science and technology.

Imagine where we could be when the rest of Australia comes on board.

Carla Sbrocchi (University of Technology, Sydney), Greta Pecl (Institute for Marine and Antarctic Studies, University of Tasmania, and the Centre for Marine Socioecology), Chris Gillies (The Nature Conservancy) and Philip Roetman (University of South Australia) are co-authors of *Building Australia Through Citizen Science*, an Occasional Paper published by the Office of the Chief Scientist (2015).

We Will Never Cure Cancer, So Should We Even Try?

Billions of dollars are spent on cancer research each year for minimal gains. Would that money be better invested elsewhere?

In 2014, cancer overtook cardiovascular disease as the leading cause of death in the world. While the incidence of cancer has continued to rise, the long-term survival rate has increased from 47% during the mid-1980s to more than 65% by 2010.

Despite this promising improvement in survival, the unique nature of the disease means it is unlikely that it will ever be declared cured. This is because there will never be a single drug that is capable of curing all forms of cancer, and the success of treatment is highly dependent on how early it is detected.

Instead, better screening techniques and the use of personalised medicine will improve the success of treatment in the coming decade, but it will never reach 100%. And even if we could cure cancer, the financial cost may be too high, especially when the money to do so could be better spent elsewhere.

In 1906 the German scientist, Paul Ehrlich, coined the term “magic bullet” to describe a single drug that could specifically seek out and kill a disease with little or no side-effects.

The magic bullet theory certainly holds true for many types of disease. Take bacterial infections as an example. When the antibiotic penicillin was discovered, it literally was a magic bullet that saved many millions of lives.

But the important thing with antibiotics, if we discount the rising problem of resistance, is that there is no variability in response between different patients. If a treatment works in one patient with a particular infection we know that it will work in another patient with the same infection. This, however, is not the case for cancer.

The biggest obstacle to curing cancer is that it is not a single disease but a family of more than 100 different diseases, all of which require different treatments. Traditionally doctors have classified cancer into groups based on the part of the body in which it is first found: breast, lung, testicular, bladder. But when we treat what we think are the same types of cancer we find that they can respond in completely different ways.

What this means is that even if a breakthrough is made for one type of cancer, its benefit is unlikely to transfer to other types of cancers. To properly cure cancer, many hundreds of different drugs will still need to be developed, each treating only a small range of cancers.

The second important factor is that doctors don't ever declare a patient as being cured because it's too difficult to know whether there are still microscopic pockets of cancer that didn't get picked up during treatment. In these cases, patients can relapse



months or years later. Instead of using terms like “cured”, doctors often refer to one- and five-year survival rates.

So if we aren't ever going to find a single drug that will cure cancer, what does the future hold?

The coming decade will herald the age of personalised medicine. Instead of classifying cancers based on the region of the body in which they are found, we are now looking at cancers at the molecular level and reclassifying them based on the particular markers we find on, or inside, the cancer cells.

For instance, there are three different markers for breast cancer: the oestrogen receptor (ER), the progesterone receptor (PR) and the HER2 receptor. After testing for these, each patient is classified as having a normal (negative) or excessive (positive) amount of each receptor. For example, one patient may be classified as ER⁺, PR⁺ and HER⁻ while another patient may be ER⁻, PR⁻ and HER⁺. In total, the combination of the three different receptor levels gives rise to six different types of breast cancer, and each needs a different cocktail of drugs.

Unfortunately, while personalised treatments tends to be much more effective, with patients enjoying better survival rates, it's a major problem from a government or pharmaceutical companies' economic perspective.



... the majority of new drugs that are approved ... only ever give the patients a few months longer to live compared with the drugs we already have available.

This raises the question: should we even be looking for a cure for cancer?

An important fact to note is that the majority of new drugs that are approved do not greatly increase life expectancy. On average they only ever give the patients a few months longer to live compared with the drugs we already have available. Given this, can we justify meeting their high costs?

Last year the National Health and Medical Research Council, which funds the majority of medical research in Australia, spent \$182 million on cancer research, mostly on the development and testing of new treatments. Likewise, Australia's largest cancer charity, Cancer Council Australia, spent \$1.6 million on cancer research funding. More than 100 other cancer charities in Australia spent many millions more on cancer drug discovery research and clinical trials.

Even bigger sums of money are spent in other countries. The National Cancer Institute in the USA has a budget of just under \$5 billion for the current financial year, and Cancer Research UK spent £460 million (A\$1.2 billion).

While not all the money spent on cancer research is for the discovery of new treatments, we have to ask ourselves, as a society, whether just a fraction of this money could provide much more substantial benefits if it was redirected? How many teachers, police, firefighters or social workers could this money be used to employ? What environmental projects won't be funded because of our continued investment in cancer drug research? How many children could be lifted from poverty and given education and opportunities they would not otherwise get?

Even if the money was kept for cancer research, it could be better spent on awareness programs, better and earlier detection methods, research programs to gain a deeper understanding of its causes, or to build more specialised cancer treatment centres so that patients get the level of care they need.

In the following decade the burden of cancer as a disease in society will continue to increase because of the ageing population. With the cost of drugs continuing to rise and the fact that there will never be a single treatment that will cure all cancers, we need to either find a way to reduce costs or redirect the money that would be spent on treatment research to other areas where it will provide the most benefit.

It is very expensive to develop, test and get approval for a new drug. Depending on who you ask, the cost of taking a drug from discovery to the market is \$1–5 billion. This makes research into new drugs a risky venture that is only offset by many years of patent-protected sales.

To be really profitable a new drug must have global sales of more than \$1 billion per year, but to achieve this status a drug needs a very large patient base to whom it can be sold.

As treatments become more personalised, the number of patients treated with a particular drug will drop remarkably. This means there simply won't be a sufficiently large patient base in the future to justify new drug development. The result may be that pharmaceutical companies won't bother exploring new drugs for personalised cancer treatment, or that they will be forced to sell the drugs at exorbitant prices.

As the average patient can't afford the price of chemotherapy drugs, the cost is pushed onto health insurance companies. Alternatively, the cost is covered by the government, which subsidises the medicines by up to 99%. Either way, new drug development leads to unsustainable health insurance premiums or government health care costs.

Nial Wheate is a Senior Lecturer in the Faculty of Pharmacy at The University of Sydney.

Our Human Right not to Be Poisoned

Thousands of new chemicals are released each year, and the toxic effects are mounting. What can we do about it?

Earth, and all life on it, are being saturated with anthropogenic chemicals and wastes in an event unlike anything in the previous four billion years of our planet's story. Each moment of our lives, from conception to death, we are exposed to thousands of substances, some lethal, many toxic, and most of them unknown in their effects on our health or on the natural world.

This has mainly happened in barely the space of a single lifetime. Collectively humanity manufactures around 144,000 different chemicals, and the US Department of Health and Human Services estimates that 1000–2000 new ones are released each year. Many of these are untested for safety.

These are the mere tip of the iceberg. Each year we also generate:

- 150 million tonnes of nitrogen and 11 million tonnes of phosphorus, mainly from farming, burning fossil fuels and waste disposal;
- 400 million tonnes of hazardous wastes, including 50 million tonnes of old computers and phones;
- 15 billion tonnes of coal, oil and gas, contributing the lion's share of 50 billion tonnes of carbon dioxide gas;
- 72 billion tonnes of minerals, metals and materials;
- up to 100 billion tonnes of rock, soil, tailings, overburden and slags from mining; and
- 75 billion tonnes of topsoil, mainly from farming and development.

These substances move constantly in both space and time. They travel on the wind, in water, attached to soil, in dust, in plastic particles, in wildlife, in food and traded goods, and in (and on) people. They combine and recombine with one another, and with naturally occurring substances, giving rise to generations of new compounds – some more toxic,

others less, and many completely unknown. They leapfrog around the planet in cycles of absorption and re-release known as the “grasshopper effect”.

Many of these substances, especially heavy metals, last for generations, creating a cumulative toxic load in the environment – and in ourselves. Their effects are, even now, being passed on to future generations of people through our genes.

Tests show that most people in modern societies now carry a lifelong chemical burden (tinyurl.com/mooul6r), that unborn babies are contaminated with industrial chemicals (tinyurl.com/ndyls8b) and that mothers' milk in 68 countries is contaminated with pesticides and other noxious substances (tinyurl.com/oj3mwgl). Around 4000–6000 chemicals – mostly pesticides, preservatives, additives and dyes – are regularly used in the growing, processing and packaging of our food.

The World Health Organisation and UN Environment Program have estimated that one in 12 people die from these environmental toxins, and around 86 million are maimed each year (tinyurl.com/o96pbo6). This toll is greater than for HIV, malaria or car crashes. One in five cancers – about two million fatalities per year – are attributable to our exposure to carcinogens in our living environment (tinyurl.com/njkzkmf). Medical scientists have warned of a silent pandemic of childhood brain damage caused by the global release of neurotoxins due to human activity, and health officials have cautioned that reproductive and gender disorders caused by endocrine-disrupting chemicals are on the rise worldwide.

Above all, health researchers are concerned at the potential impact of billions of mixtures of thousands of different substances combining in our

diet and living environment, which they now increasingly link to conditions including developmental disorders, sexual dysfunction, obesity, cancers, heart disease, and nerve and brain diseases including autism, depression, Parkinson's and Alzheimer's.

Current human life expectancy figures are based on historical data, and on medical successes gained with vaccines, antibiotics and sound public health. The impact of the toxic flood may be temporarily masked by this success, but many scientists fear this will not last long because “lifestyle” diseases and society's toxic burden are on the rise.

We cannot afford to wait until death rates rise. We must act now to prevent them doing so.





The Stockholm Convention has so far banned just 19 out of our 144,000 chemicals, and appears powerless to stem the global flood of new releases, especially as the bulk of the world's chemical output is now shifting to poorly regulated Third World locations. From Minamata to Bhopal to Tianjin, a string of toxic disasters has demonstrated the futility of legal action against individual companies to stem global contamination. However, blaming industry and calling for tougher regulation will not solve the problem of the poisoned planet.

We need a smarter way to protect society and all future generations from the toxic flood. This starts with recognising that we are the ones who generate the market signals that lead to the mass

production and ill-considered release of toxins. Every act of consumption on a crowded planet has chemical consequences. Every dollar we spend sends a signal to a string of industries to produce, use or emit a mass of chemicals. Those innocent signals, in all likelihood, are now killing more people per year than in World War II.

In a sense we are all getting away with murder. This uncomfortable thought is essential if modern society is to take effective action to clean up the Earth and protect our children in the future. If we have given rise to the problem by demanding goods that are produced using toxic substances or with toxic processes, then we alone have the power to correct it. It is already clear that governments do not have the capacity or the will to regulate a global toxic flood. Regulation is important, but if we rely on rules alone to protect our children, the evidence indicates they will not succeed.

In a globalised world only we, the people, are powerful enough – as consumers – to send the market signals to industry to cease toxic emissions. And to properly reward it for producing clean, safe, healthy products or services. For the first time in history we have the means to share a universal understanding of a common threat and what we can each do to mitigate it.

Through the internet and social media, concerned citizens and parents are already mobilising around the world – reaching out to one another across cultural, ethnic, religious, linguistic and economic borders. Concerned citizens and parents are joining hands at lightspeed to cleanse our poisoned planet. This is an expression of people power and global democracy like never before.

Many exciting new technologies and approaches are being trialled to clean up our planet, like green chemistry, industrial ecology, product stewardship and zero waste. But we have to find ways to encourage industry to adopt, and the most

effective of these are consumer-generated market signals.

Far from being harmful to industry, this universal demand for clean, safe products will open fresh markets, create more jobs, built new companies and generate greater prosperity and better health.

There are many ways in which we can all contribute to detoxifying our world:

- form a partnership of concerned citizens, industries and regulators;
- demand a new human right not to be poisoned;
- eliminate coal, oil, gas and fossil fuels as the primary sources of most contamination;
- eliminate toxins from the food chain through regulation;
- institute worldwide preventative healthcare to replace the “get-sick-and-treat-with-more-chemicals” approach);
- incorporate the teaching of ethics with chemistry in order to train young scientists, like doctors, to “first, do no harm”;
- educate children to choose non-toxic products;
- reward industry by buying green;
- implement zero waste, green chemistry and product stewardship in our consumption patterns, lives and occupations; and
- test all new chemical products for health and environmental safety.

Every person in the world has a right to life, liberty, personal security, marriage and family, equality, work, education, freedom of belief and freedom from torture. These rights are available to each of us under the Universal Declaration on Human Rights. It is more than a little disturbing that there is no human right not to be poisoned – a privilege enjoyed by all our ancestors until recent times.

Unless and until we have such a right, there will probably never again be a day in history when we and our children are free from man-made poisons.

Julian Cribb is the author of *Poisoned Planet* (Allen&Unwin). This article is based on his keynote address to the CleanUp 2015 Conference in Melbourne.

Epigenetic Markers Predict Male Sexual Orientation

Epigenetic differences between male twins has been used to identify sexual orientation with up to 70% accuracy, according to unpublished results presented at the American Society of Human Genetics 2015 annual meeting.

“The key issue here is that the authors have searched through the entire genome to identify some difference between discordant twins. Given the number of tests, it is likely that some regions will show up as differentiated by chance. Without validation of the result in an independent data set it is not really possible to know whether there is any substance in this claim.”

Prof Gil McVean, Professor of Statistical Genetics, University of Oxford

“The authors of this abstract utilized a very small number of samples and discovered certain epigenetic markers could be associated with sexual orientation. However, I am not sure whether ‘the predictive model’ as claimed in the abstract is a correct term given the overall sample size. At best the authors could only claim the potential association, but not predicting power.

“It is unclear what tissues they used for epigenetic profiling. Blood DNA is likely the source, which could be the caveat of this study. It has been continuously debated whether the methylation status of blood DNA could be used as epigenetic biomarker for brain-related phenotypes. In addition, additional cytosine modifications have been discovered in recent years and the experimental system used in this study could not distinguish some of these modifications. The interpretation of their results could be limited.

“The observed epigenetic changes, particularly if from blood DNA, unlikely determine the complex behaviors, such as sexual orientation. These observations are potentially intriguing, however, interpreting these results certainly needs caution.”

Dr Peng Jin, Professor of Human Genetics, Emory University

“Epigenetic marks are the consequence of complex interactions between the genetics, development and environment of an individual. Epigenetics is still a young science, and although there is great potential very little is known about the mechanisms that shape the epigenetic landscapes of an individual. Simple correlations – if significant – of epigenetic marks of an individual with anything from favourite football player to disease risk does not imply a causal relationship or understanding.”

Dr Eric Miska, Herchel Smith Chair of Molecular Genetics, The Gurdon Institute and Department of Genetics, University of Cambridge

“This new study investigates the possibility that specific epigenetic marks on the genome can be used as markers that indicate male heterosexual versus homosexual behavior. Note that this is not the same as finding that specific epigenetic marks

are causing differences in sexual orientation. Thus, the authors’ claim that they have ‘new insights into the biological underpinnings of sexual orientation’ appears to be overstated.

“The observed differences in epigenetic marks could arise as a consequence of the unknown biological factors that cause heterosexual versus homosexual behaviors, or due to lifestyle differences. Indeed, epigenetic marks differ between tissues and cells and, although it is not stated, the authors presumably analyzed blood samples from twins, rather than specific regions of the brain that control sexual behaviors and attraction. Therefore, the study does not provide evidence for ‘epigenetic influences on sexual orientation’, but it appears to have identified candidates for further investigation and an epigenetic signature that has some predictive utility in twins.

“Overall, the importance of these findings will hinge on how reproducible they are in future studies that include larger groups of heterosexual and homosexual individuals.”

Dr Christopher Gregg, Assistant Professor of Neurobiology & Anatomy and Human Genetics, University of Utah

“Studies that associate biomarkers with particular traits are notoriously prone to false-positive results due to the tendency of these studies to find spurious associations that are down to sheer chance. The key test is whether the associations are found in a completely independent study population.

“From the abstract this confirmatory test does not appear to have been performed in this study. Without it, the results should be considered to be suggestive and preliminary but in need of verification before any firm conclusions can be drawn.”

Prof Johnjoe McFadden, Professor of Molecular Genetics, University of Surrey

“With only a research summary (abstract) to work with it is difficult to give a full appraisal of the research. Nonetheless, to claim a 70% predictive value of something as complex as homosexuality is bold indeed. I wait with baited breath for a full peer-reviewed article.

“While there is strong evidence in general for a biological basis for homosexuality, my personal impression has always been one of a multiple contributory factors, including life experiences. My gut feeling is that, as the complete story unfolds, the association may not be quite as simple as the summary (abstract) and press release suggest. The important thing to note however is the mounting evidence that homosexuality is a perfectly normal trait segregating in human populations.”

Prof Darren Griffin, Professor of Genetics, University of Kent

Transcranial Brainwashing

Is it possible to significantly change a person's beliefs by stimulating the brain?

Religious convictions and parochial beliefs about racial or national groups are strong motivators of human behaviour, with both beneficial and harmful social consequences. These beliefs play a significant role in human decision-making: when facing a challenge or threat, people are most likely to demonstrate their adherence to religious and political ideologies.

Yet a study reported in *Social Cognitive and Affective Neuroscience* has reported that the strength of such beliefs may be open to modification through transcranial magnetic stimulation (TMS), with treated participants reporting a diminished degree of agreement with religious statements and less negative attitudes towards immigrants.



Previous studies have established that, when confronted by situations characterised by conflicting values or complex dilemmas, decision-making is strongly influenced by pre-existing and often parochial ideologies. The strength of these beliefs varies across contexts, along with their impact on decisions. Previous research has found that cues for threat tend to elicit stronger expressions of adherence to beliefs, and neuroimaging has demonstrated that the brain region that's central to invoking relevant beliefs in decision-making is the posterior medial frontal cortex (pmFC).

The study by US and UK researchers recruited 38 undergraduate students, with each reporting they held significant religious beliefs and conservative political views. Participants in the experimental condition received TMS to the pmFC for a period of 40 seconds, a process that reduces neural activity in this region for up to an hour. Control participants underwent a similar process, but with a low level of TMS that has no effect on the functioning of the pmFC.

To induce threat, all participants were asked to write brief comments on the subject of their own death, a task selected due to its association with religious beliefs. The strength of religious belief was subsequently assessed through a questionnaire asking participants to indicate their agreement with statements such as "There exist good personal spiritual beings, whom we might call angels" and "Some people will go to Hell when they die".

Group prejudice was examined by having participants read an article critical of their country (USA) ostensibly written by a recent immigrant, and assessing their responses through degree of agreement with statements such as "I like the person who wrote this" and "I think this person's opinions of America are true".

The researchers found that those who had received TMS reported significantly less conviction in their beliefs concerning God, angels and Heaven following a reminder of death than those in the non-TMS control group. Those receiving TMS rated the immigrant's article significantly more positively than the non-TMS controls. Together, these findings of reduced religiosity and lessened disparagement of immigrants supported the hypothesis that disruption of the pmFC temporarily weakens the strength of previously established beliefs or attitudes, limiting their effect on decision-making.

How does TMS of the pmFC affect people's beliefs? The researchers speculated that the pmFC is usually active when a person is confronted with a problem related to conflicting ideological values or insoluble dilemmas, and that it engages relevant belief systems in decision-making. In this experiment, when the participants are primed to think about their own

deaths, the pmFC draws upon and amplifies established religious beliefs. When presented with an immigrant's criticism of their nation's values, the pmFC elicits and intensifies existing beliefs about "out-group" members. If the pmFC has been experimentally inhibited through application of TMS, the participants are less prone to draw upon these established beliefs, and thus display reduced religiosity and denigration of critical out-group members.

The study illuminates aspects of the neurobiology of belief and decision-making, and demonstrates that it is possible to influence the strength of religious convictions and parochial beliefs through transcranial magnetic stimulation. This is a fascinating notion that also raises profound ethical questions about individuality and the right to one's own beliefs, however strange or bigoted they might appear to others, or however extreme the behaviours to which they lead.

A/Prof Tim Hannan is Head of the School of Psychology at Charles Sturt University, and the Past President of the Australian Psychological Society.



The Rich Get Healthier

We're getting healthier and living longer, but the rich more than the poor.

What would you prefer: to get a rise of \$50 per week when everyone else (for the same amount of work) gets \$100, or that everyone gets \$30 per week? Or would you prefer a world where you live an extra 5 years and everyone else lives an extra 10 years, or where everyone lives an extra 3 years?

It doesn't really matter what you want, here's what you're getting, at least in Australia: everyone is getting healthier and living longer, but some are getting healthier faster, and the gap is increasing.

Or so a recent study from Sydney University tells us. In NSW in 2002, 55% of adults had a "high lifestyle risk", defined as two or more of the following unhealthy behaviours: high alcohol consumption, physical inactivity, low fruit and vegetable intake, and smoking). By 2012 that was down to 45%. New South Welshfolk today are drinking less, smoking less, eating more fruit and veg, and getting more exercise.

So far, plain sailing. However, in the richest 20% of the NSW population, the improvement has been much greater: down from 46% unhealthy in 2002 to 35% in 2012. In the poorest 20% it only fell from 57% to 54%. The gap has increased: in 2002, there were 1.24 unhealthy poor people for every unhealthy rich person. Now there are 1.53.

An earlier study covering the period 1989–2001 found the same trends in Australian capital cities. Over that period, 3% of the poorest group gave up smoking compared with 5% of the richest. An extra 3% of the poorest group became sufficiently active, while 8% of the richest group started exercising.

So what's driving increases in health inequalities? For some, the answer is clear. In their book *The Spirit Level*, David

Wilkinson and Kate Pickett claim that physical and mental health are considerably worse in countries where inequality of wealth and income is greater, regardless of the overall level of wealth of the country. There is, they claim, something about inequality in itself that causes ill-health. Wilkinson and Pickett speculate that what's causing this may be stress generated by comparison anxiety: stress levels increase when you see the Joneses are doing better than you. This generates an inflammatory response, and everything goes downhill from there. Equality keeps us on an even keel.

Wilkinson and Pickett's argument has come in for some heavy-duty criticism: they have been accused of sins both agricultural (cherry-picking) and industrial (data mining). For example, South Korea and the Czech Republic have been mysteriously excluded from their datasets. They appear at times to be using some fairly dodgy estimates of inequality, and iffy confusing correlation with causation. A lot of their results also seem to be driven by the outlier Scandinavian countries (which are both very equal and very healthy).

Even if health inequalities are not being driven by income inequalities, they're being driven by something. In Australia, at least, the rising tide is lifting some boats faster than others. But what if health is getting worse: do we get less inequality? Does a falling tide fall faster for the higher boats?

Surprisingly, the answer may be yes, at least in some countries. Consider obesity. Adults are still getting fatter pretty much around the world.

But is the gap in obesity increasing? Between 1995 and 2011, Scots as a whole got fatter but inequalities were reduced. In 1995, 16% of semi-skilled and unskilled Scottish workers were obese, and this had risen to 25% by 2011. In professional and managerial jobs, the rise has been from 16% to 30%. North of the border, fat cats are getting fatter faster than manual workers. The same appears to have happened in Canada between 2000 and 2010. In the US, the gap has been relatively stable since 1971.

Happily, what is true inside countries is not true across countries. Across countries, the gap is closing, largely because of the rapid modernisation of China and India, whose economies are going full steam ahead. In 1920, life expectancy at birth in China was 31. It is now 74. In India it was 29 in 1930, and is now 65. These are increases of 42 and 36 years. Over the same period, life expectancy in Australia increased from 65 to 82, an increase of just 17 years.

Does it matter? If we're all getting healthier, surely that's a good thing. I guess it depends on how you feel about everyone else getting that \$100 while you only get \$50. It depends on what floats your boat.

Professor Tim Olds leads the Health and Use of Time Group at the Sansom Institute for Health Research, University of South Australia.

A New Cause for Three Global Mass Extinction Events

Dangerously low levels of trace elements might be implicated in three mass extinctions.

Throughout the past 600 million years there have been five major mass extinction events and a host of smaller biotic crises, each of which saw the demise of large swaths of life on Earth and in the oceans. While some of these events are very well studied, such as the killer asteroid that wiped out the dinosaurs 66 million years ago, others are more enigmatic and entertain a variety of possible causes.

The first three extinction events took place near the end of the Ordovician Period (c. 445 Ma), end of the Devonian Period (385–359 Ma) and at the end of the Permian Period (252 Ma). The most devastating of these events was the end of Permian event, which wiped out 96% of all marine species and about 70% of life on Earth. The likely causes are from massive volcanic eruptions on a scale never before seen, with other effects that include a runaway greenhouse effect triggered by methane release from the seafloor. Because the devastation was so severe, recovery took around 10 million years.

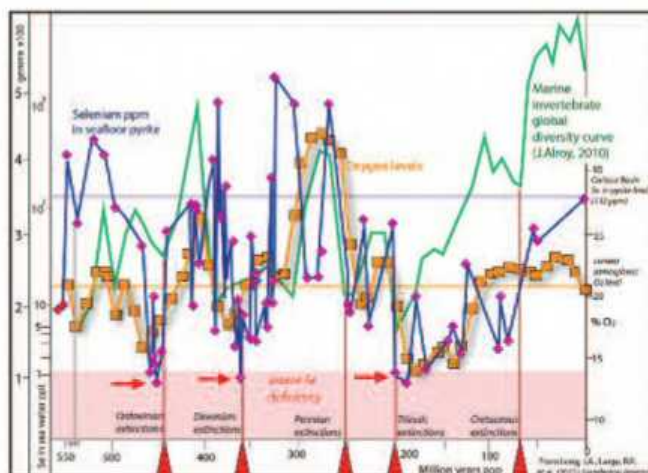
The big extinction event at the end of the Ordovician is linked to glaciation and widespread anoxia, or loss of oxygen in the seas. About 57% of all genera were wiped out in the oceans, making it the second largest of all extinction events. The reliability of interpreting the past oxygen levels of the Earth is the key to understanding this event – the anoxia may have been brought on by another cause.

Prof Ross Large's team at The University of Tasmania has been charting the abundance of trace elements in the past oceans, and now has more than 2000 samples spanning 3.5 billion years. His Laser Ablation-Inductively Coupled Mass Plasma Spectrometry Lab is one of the few in the world to be capable of measuring very small amounts of trace elements from sea-floor muds containing pyrite. Two new papers published this year in *Gondwana Research* show that dangerously low levels of certain trace elements, like selenium, might be implicated as a new factor in three major mass extinction events.

Most life on Earth needs selenium in very specific amounts. Too much or too little is toxic. Today's oceans contain about 155 ppt of selenium in their surface waters, changing slightly with depth. Tolerance levels of selenium for phytoplankton, molluscs, fish and many terrestrial plants and animals are very well-known due to aquaculture requirements.

If the oceans rapidly dropped their levels of selenium by two orders of magnitude, would food chains likely be affected? This is precisely what happened at the end of the Ordovician, Devonian and Triassic Periods.

The real question is whether selenium, which seems to be a good proxy for past oxygen levels, was the prime driver for the



Times when severe selenium depletion in the oceans (red arrows) coincided with three major mass extinction events.

loss of oxygen in the oceans that caused the extinctions, or was itself the main cause of extinctions.

The cycle of nutrients in the oceans is driven by plate tectonics. The uplift of mountains at plate margins causes erosion of crustal surfaces, enabling trace elements to wash into rivers and end up in the seas. When erosion is prolonged and tectonics is slow, the supply of these nutrients slows down, and the depletion of certain elements begins. Only activation of the Earth's engine, to drive more mountain-building, seems to set the cycle back to normal again.

Yet mass extinctions have their bright side. Without them, new life couldn't emerge. Mammals rose to prominence after the decline of the dinosaurs, and thus we are here today, thanks mainly to a mass extinction event 66 million years ago.

John Long is Strategic Professor in Palaeontology at Flinders University, and current President of the Society of Vertebrate Paleontology.



Our Wastewater Is a Valuable, Recoverable Resource

Australia can quickly turn our wastewater from a burden to a benefit.

Australia is literally wasting millions – maybe billions – of dollars each year by not extracting the full value of its wastewater.

Phosphorus, nitrogen and energy are necessary for life, and continued extraction of non-renewable forms of these resources is ultimately not possible. Each of these is contained in our wastewater, which is rich in nutrients, carbon, energy, and other inorganic and organic resources.

So how do we optimise this value and avoid wasting these water-borne resources, which have the proven potential to generate energy, produce fertilisers and save money?

The solutions to this waste are available to us now. They just require a strong focus on recognising the potential and implementing the technology. The upside is the financial returns available to those who grasp the challenge.

Population growth, increasing demand for natural resources, rising costs and community expectations place pressure on policymakers to manage natural resources and require the water industry to develop innovative and more efficient processes.

Resource recovery can preserve original natural resources, minimise waste generation and maximise value creation from waste products.

The Academy of Technology, funded by the Australian Water Recycling Centre of Excellence, has recently completed a major investigation of the issue and published its report. *Wastewater: An Untapped Resource?* took a financial prism to the issue, and made some strong recommendations that could see Australia make some strong strides forward in wastewater resource recovery.

Financing

The report recommends using true “net present value” analyses for resource recovery projects, considering revenue streams in addition to the capital and operating costs and elimination of operating costs. Financial analysis should include the concept of “value at risk” and a “real options approach” to deal with future financial investment uncertainty.

Innovative Partnerships

The Australian wastewater industry should take the lead in developing value-adding and innovative partnerships with private investment groups to facilitate investment in resource recovery. Upstream, this would mean the active development of Public–Private Partnerships, relationships with technology suppliers and the use of build–own–operate partnerships with private providers to produce resource recovery products. Downstream, it would mean reaching out to energy, agriculture and

horticulture users of products to ensure a deep understanding of the associated value propositions.

Technology Developments

Economic analysis has shown that several of the newer technologies and technology combinations with low energy consumption will in future be economic at larger scales. The main economic barrier is market readiness rather than technical performance. Previous government-level R&D funding has focused mainly on water supplies rather than wastewater treatment. Australia should remain close to the new wastewater treatment technology developments and participate in associated international and local RD&D studies.

Fertiliser Potential

International experience shows that resource recovery nutrient products can be marketed with high retail price margins if the market is properly developed and the benefits to customers are demonstrated. Fertilisers from resource recovery are also sustainable, a key market differentiator. The unique value of resource recovery products has not yet been fully developed in Australia. Australia should increase its R&D on the agricultural and horticultural benefits of resource recovery fertiliser products, especially for niche retail markets.

Better Regulation

The regulatory frameworks surrounding water, wastewater processing and waste disposal often present an impediment to investment in resource recovery. This is due to differences in jurisdictions, differences in requirements between “waste” and “fertiliser”, and the imposition of a time-consuming, costly and onerous interface for private investors. On the other hand, stricter effluent water nutrient content regulations are often a driver for beneficial recovery of nutrients. Commonality and simplicity in regulations for water and waste across state jurisdictions would facilitate investment in resource recovery.

Since many resource recovery products are used as fertilisers, they should be treated similarly to fertilisers in terms of regulation of trace element contamination. Similarly, energy generation from resource recovery is renewable and should be regulated accordingly, including appropriate levels of feed-in tariff for the electricity generated and renewable energy incentives, the report states.

If Australia picked up on these recommendations it could quickly turn our wastewater from a burden to a benefit.

Dr John Burgess FTSE is a chemical engineer who led the working group that developed *Wastewater: An Untapped Resource?*

Pulsar Glitches Help to Weigh a Star

Researchers from the University of Southampton have developed a new method for measuring the mass of pulsars, highly magnetised rotating neutron stars formed from the remains of massive stars after they explode into supernovae.

Until now, scientists have determined the mass of stars, planets and moons by studying their relative motion using gravitational interactions between the two as the basis for their calculations. Southampton mathematicians have now found a new way to measure the mass of young pulsars using the principles of nuclear physics, rather than gravity, to work out their mass.

All previous precise measurements of pulsar masses have been made for stars that orbit another object, using the same techniques used to measure the mass of the Earth or Moon. This new technique is so different it can even be used for pulsars in isolation.

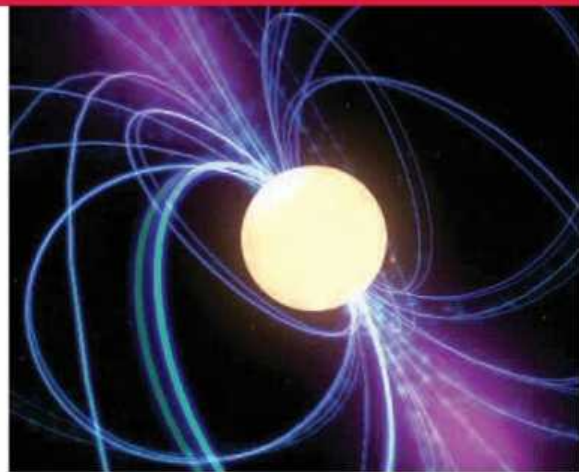
Pulsars emit a rotating beam of electromagnetic radiation, which can be

detected by telescopes when the beam sweeps past the Earth like the beam of a lighthouse. Renowned for their incredible rotational stability, young pulsars occasionally experience so-called “glitches” where they speed up for a very brief period of time.

It’s believed these glitches arise as a rapidly spinning superfluid within the star transfers its rotational energy to the star’s crust, the component that is tracked by observations.

Imagine the pulsar as a bowl of soup, with the bowl spinning at one speed and the soup spinning faster. Friction between the inside of the bowl and the soup will cause the bowl to speed up. The more soup there is, the faster the bowl will be made to rotate.

Lead researcher, Dr Wynn Ho, has collaborated with his colleagues to use new radio and X-ray data to develop a novel mathematical model that can be used to measure the mass of pulsars that glitch.



Pulsars are known for their superb precision, but glitches can interrupt the regular timing behaviour when the stars are young. Credit: NASA/Goddard Space Flight Centre

The magnitude and frequency of the pulsar glitches depend on the amount of superfluid in the star and the vortices within. By combining observational information with the nuclear physics involved, one can determine the mass of the star.

The team’s results have important implications for the next generation of radio telescopes like the Square Kilometre Array and the Low Frequency Array. The discovery and monitoring of many more pulsars is one of the key scientific goals of these and other similar projects.

David Reneke is an astronomy lecturer and teacher, a feature writer for major Australian newspapers and magazines, and a science correspondent for ABC and commercial radio. Subscribe to David’s free Astro-Space newsletter at www.davidreneke.com

Jupiter’s Great Red Spot Is Shrinking

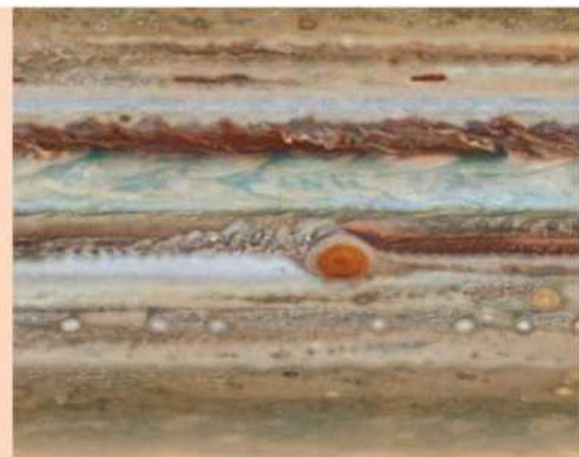
A broad range of features have been captured in new images of Jupiter, including winds, clouds and storms. The scientists behind the new images took pictures of Jupiter using Hubble’s Wide Field Camera over a 10-hour period, producing two maps of the entire planet. These maps make it possible to determine the speed of Jupiter’s winds, to identify different phenomena in its atmosphere and to track changes in its most famous features.

The images confirm that the huge storm that has raged on Jupiter’s surface for at least 300 years continues to shrink. The storm, known as the Great Red Spot, is seen swirling at the centre of the image of the planet. It has been decreasing in size for some time but now the rate of shrinkage seems to be slowing again, even though the spot is still about 240 km smaller than it was in 2014.

At the centre of the spot, which is less intense in colour than it once was, is an unusual twisted, wispy filament spanning almost the entire width of the vortex. It’s distorted by winds that are blowing at a massive 540 km/h.

Another feature of interest, just north of the planet’s equator, is a rare wave structure, spotted on the planet only once before by the Voyager 2 spacecraft decades ago. Astronomers began to think its appearance was a fluke as nothing like it has been seen since – until now.

The current wave was found in a region dotted with cyclones and anticyclones. Similar waves called baroclinic waves sometimes appear in the Earth’s atmosphere where cyclones are forming. The wave may originate in a clear layer beneath the clouds, only becoming visible when it propagates up into the cloud deck.



New Hubble images show dramatic changes in Jupiter’s atmosphere and shrinkage of the famous Giant Red Spot.

Credit: NASA/ESA

A collection of maps will now be built up over time to help scientists not only understand the atmospheres of giant planets in the Solar System, but our own planet and of the planets that are being discovered around other stars.

The Needles Are as Thin as the Evidence

Practitioners of dry-needling swear by it, yet there is no evidence it will relieve your muscular aches and pains.

With alternative medicine now coming to a university near you, and the Free Trade Agreement with China pledging to welcome and promote traditional Chinese medicine in Australia, you can expect to see many more promises online and elsewhere about the alleged benefits of alternative health practices.

Dry-needling is among them. Practitioners of dry-needling swear by it, yet it is not the miracle treatment for your muscular aches and pains.

In science you cannot prove anything, only support it with evidence, yet allied health professionals who practice dry-needling often sell it as a proven and effective remedy for assorted muscle-related issues. Far from standing on the elusive pedestal of being proven, dry-needling is barely supported by good quality evidence.

Before going any further, an important distinction has to be made between dry-needling and acupuncture as the two come from the same stable and are often conflated by practitioners.

Dry-needling involves the insertion of acupuncture needles into painful nodules of taut muscle known as trigger point sites with the aim of relieving pain. It seems to be popular among those who profess to treat sports injuries.

Acupuncture is the esoteric belief that sticking needles into prescribed places on the body unblocks invisible energy channels and somehow heals the patient. Dry-needling proponents follow this line.

The adverse events associated with both treatments are quite similar. Bleeding, bruising or swelling in the local area where the needle penetrated is common. More serious effects such as pain or numbness lasting up to 2 weeks are also possible. Life-threatening adverse events such as pneumothorax, where a lung collapses, are rare but do happen.

The Australian Physiotherapy Association states that the evidence for dry-needling has increased substantially over the past decade. They go on to say that evidence supports dry-needling as a remedy for lower back pain, migraine headaches, pelvic girdle pain, knee osteoarthritis, elbow pain and shoulder issues.

However, the literature often describes the evidence for dry-needling as unsatisfactory and of low quality. While a systematic review published in 2013 (tinyurl.com/odmnh9t) emphatically recommended the use of dry-needling compared with placebo or sham, the review completely contradicted its own results, which actually demonstrated that dry-needling was either worse or no better than sham treatments.

A Cochrane review (tinyurl.com/nj8d7cn) found that while the evidence was insufficient to make any recommendations about dry-needling being used as a sole therapy, it may be a minimally useful adjunct to normal care. Other reviews have pointed to the lack of quality of scientific studies as well as their scant number.

As is usual with alternative treatments, some practitioners will stand up at this point and defend dry-needling by saying that it works for their patients, and that they have seen amazing results. To those individuals I would say that we use evidence-based practice and not practice-based evidence for a reason. Anecdotes about treatments are coloured by the thoughts and feelings of the practitioner and the patient, which is why we use single, double and even triple blind experiments. We do as much as we ethically can to remove bias.

Being invested financially or emotionally in a treatment, such as dry-needling, can certainly introduce bias and therefore cloud judgement. Consequently, with ethics in mind, the financial cost and the potential for an adverse event from dry-needling cannot be justified. So far no substantial benefit to the patient has been shown by rigorous scientific research, and it costs them their hard-earned cash.

But if personal revelations are to be given any credibility, from unfortunate personal experience I can say that someone sticking a needle into a sore point of muscle hurts a lot, but what hurt more was the \$75 charge at the end of the session.

Marko Petrovic is an exercise physiologist who is currently studying Mechanical Engineering at Curtin University.

"The reputation of a scientific society is judged not just by the high academic standards it achieves but by the low standards it tolerates and ignores!" – Prof Alastair MacLennan (Vice-President)



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Things Change. Get Used to It

How concerned should we be that only 39% of psychology research can be replicated?

In the June edition of *Australasian Science* I wrote about the reproducibility of scientific studies. I was mainly concerned that there were studies in pseudoscience where replication did not indicate the presence of any effects at all, and generally this is because the original studies or experiments were conducted without proper controls or procedures. The fact that much of this “research” doesn’t stand up to closer investigation is generally ignored by pseudoscientists, although they are very quick to point out that much of what is published in real scientific journals also fails the replication test.

There was much glee in woowoo world earlier this year when it was suggested that 50% of the content of medical journals may either be incorrect or out of date. This is no surprise to people who understand how the science of medicine advances.

As an example, it is perfectly reasonable to assume that papers about effective treatments for bacterial diseases were largely reduced to the status of historical relics after the discovery of antibiotics. Similarly, imaging techniques like PET and MRI made much of what was known about the treatment of physical conditions obsolete, and the changes that might result from increasing knowledge about the human genome and neuroscience will send a lot of what we now know into the dustbin.

Science is like that. It is a work in progress, we don’t know everything, and if we did science would stop.

More relevant to the issue of reproducibility is a study recently described (not “published”) in *Science*. The study looked at 100 papers published in second-tier psychology journals and found that on average only 39% of the results could be replicated. This finding united the pseudoscientists and those who claim that psychology is not a science.

The investigators’ findings can be summed up in this quote: “Generally evidence was weaker on replication. The stronger the evidence was to begin with, however, including a larger effect size, the more likely the results were reproduced”.

The second sentence is hardly news, as you would expect stronger effects from better evidence to give a result closer to what is happening in reality.

My initial reaction was surprise that the figure was as high as 39%. The study looked at papers in the areas of cognitive and social psychology, with cognitive studies being more replicable than social psychology research. This is not really surprising because the two areas look at different parts of the human experience.

Cognitive psychology is largely about measurement to infer internal processes that cannot be directly measured or in many cases even described by the subject. This would lead to the



expectation of a somewhat lower variability between test subjects, both in a single study and over a period of time.

Social psychology, on the other hand, is much more about observation, motivation, personality and subjective experiences that can be described by the subject. We would expect a high variability across a range of subjects, and even for the same subjects at varying times.

People aren’t like electrons or photons or atoms of elements or many of the other things dealt with in the so-called “hard” sciences. Every person is unique in the cells that make up their body and the experiences and knowledge that make up their personality, and this even applies to identical twins. I am not the same person that I was 10 years ago because events in those 10 years have reshaped both what and how I think. When people talk to me about IQ testing I like to point out that the most recent time I was tested showed that I had dropped five points from when I was tested at high school. This doesn’t mean that I’m less smart now, because the denominator in the equation is a lot larger.

It is this variability, both inter- and intra-person, that makes any form of psychological study difficult to replicate. Even if the same subject group is used for the second occasion and everything else is kept the same you would expect the results to be different, and this is even more likely with studies in social psychology. None of this, however, invalidates the idea of research in the social sciences.

One aspect that needs to be considered in any examination of replication is publication bias. Journals want to publish material that is new, exciting and different to what has gone before. A paper that says “We have exactly replicated the findings of paper X as published in an earlier addition of journal Y” is hardly going to excite journal editors and push it into the next edition, but that is another topic for another day.

Peter Bowditch is a former President of Australian Skeptics Inc. (www.skeptics.com.au).

Chytrid and Frogs in Australia's High Country

Science is helping conservation managers deal with the curse of chytrid fungus. While the threat has devastated many frog species, there is reason to be hopeful.

Frogs are in trouble. A devastating disease called chytridiomycosis has been wiping them out, often from pristine habitats. The disease is caused by amphibian chytrid fungus, which disrupts the skin function of infected frogs, leading to cardiac arrest.

Since the identification of chytrid fungus by Australian researchers in 1998, the pathogen has been documented in more than 500 amphibian species around the world. Fortunately the pathogen is not universally deadly, with some species demonstrating high resistance. However, many species are highly susceptible and the pathogen has been identified as the primary driver of decline for more than 200 species of frog.

It's believed the pathogen may have originated from Brazil. The earliest record of chytrid in Australia is from a preserved frog specimen collected in 1978 in south-east Queensland. From its potential introduction in Brisbane, chytrid appears to have spread rapidly both north and south.

Over the past 3 years we have focused on the long-term impacts of chytrid on frogs in the Australian high country – a region that is home to several endemic species. In the mid-1980s mysterious frog declines were reported from the region. We can now be confident that these declines were caused by chytrid. In conjunction with David Hunter from the NSW Office of Environment and Heritage, we have examined how these species are faring three decades later.

Some species are in a continued state of decline, and are being pushed closer to extinction. These declining species include some of our most iconic fauna, the corroboree frogs. The northern corroboree frog was once highly abundant in the Kosciuszko and Namadgi national parks. Populations were decimated by chytrid in the 1980s, and only a handful of remnant populations survived.

Unfortunately for the northern corroboree frog, the common eastern froglet – a highly resistant species – also remains abundant at these sites. In ongoing research, we have shown that the froglet acts as a reservoir host that carries infection but is rarely killed by the disease. This reservoir host amplifies the impact of chytrid in corroboree frog populations. Although the prognosis for both corroboree species is alarming, understanding the mechanism controlling chytrid dynamics is facilitating the development of conservation strategies.

For other species such as the endangered alpine tree frog, the situation appears a little better. The alpine tree frog also experienced major declines but remnant populations now appear rela-

Photo: David Hunter



Artificial ponds in natural breeding habitat in Kosciuszko National Park, where captive and wild-bred eggs from the critically endangered southern corroboree frog have been placed to prevent contact with co-occurring reservoir hosts and eliminate mortality from premature drying of ponds.

tively stable despite the continued presence of chytrid. Studying these populations, we have found that their persistence is facilitated by high juvenile frog recruitment.

During the breeding season, the prevalence of chytrid can exceed 90% in adults, resulting in very low survival. Crucially, though, the pathogen is rare in tadpoles and juvenile frogs. This allows the next generation to disperse into woodland habitat free of the disease. Chytrid is aquatic and individuals have a low risk of becoming infected in terrestrial environments. However, when they return to wetlands to breed they become infected. Luckily, adults are able to breed before succumbing to the disease.

In the foothills of the Snowy Mountains, the whistling tree frog, a close relative of the alpine tree frog, is bouncing back. Surveys in the 1970s found that whistling tree frogs were everywhere on the NSW southern tablelands, but populations crashed in the 1980s.

When we commenced our surveys in 2011, we found that the species was present in many areas where it had been absent two decades earlier. Ongoing surveys in 2012 and 2013 demonstrated that the species is re-expanding into habitat occupied decades ago. While more work remains to be done on the mechanism facilitating recovery, we found that sites that retained frogs during the cycle of population decline and recovery had high quality habitat.

Without conservation interventions, the number of Australian species driven to extinction by chytridiomycosis will almost certainly rise. While preserving habitat is important, it is not enough on its own; direct management is needed. We are now developing management actions that focus on reducing chytrid fungus in the environment or on frogs, and increasing the capacity of populations to persist despite the high mortality associated with disease.

The chytrid threat has been extremely daunting over the past 15 years. However, our research indicates we are now at a turning point, with the potential to make real progress in the management of this terrible disease.

Ben Scheele is an associate of the ARC Centre of Excellence for Environmental Decisions. He is currently based at James Cook University.

Nuclear Waste Returns, But Where Will It Be Stored?

Australia's nuclear waste is being returned from France, and New Zealand is finally reporting on the state of its environment.

Australia's radioactive chickens are coming home to roost. The spent fuel rods from the old HIFAR reactor at Lucas Heights, now decommissioned, were sent to France for reprocessing by the Australian Nuclear Science and Technology Organisation (ANSTO). The treatment by the French company AREVA removes useful elements like uranium and plutonium, then places the remaining waste in glass to be returned to Australia. Under French law, the waste must leave France by the end of this year. However, Australia still does not have a repository for the intermediate level waste that will be on its way back here very soon.

ANSTO says that the waste will be transported on "a nuclear-rated ship" to Australia, then taken by truck to a temporary store at Lucas Heights. "Consistent with security requirements and practice established during nine previous export operations, ANSTO will not confirm the destination port, land route, or timing." But ANSTO does have permission to retain the waste at their site "until the National Radioactive Waste Management Facility is sited, constructed and licensed". Unfortunately, nobody knows where that will be or when it will be available.

With a change in Minister after Malcolm Turnbull displaced Tony Abbott as Prime Minister, there will be another delay in this long-running saga. The Commonwealth government withdrew its proposal for a waste repository in South Australia in the face of opposition from the State government. It then tried to get approval for a site in the Northern Territory, but the proposal for Muckaty Station was also withdrawn after being challenged in the Federal Court by traditional owners of the land.

The previous Minister, Ian MacFarlane, was confident that there would be several expressions of interest from land-owners or local councils wanting to host the facility, but nothing had come to light before he lost his position as part of Turnbull's ministerial reshuffle.

New Zealand has finally recommenced national environmental reporting. Regular reports on the state of the environment have been an obligation since the 1992 Rio Earth Summit, but New Zealand has been missing in action since 2007. There has been pressure from the OECD for New Zealand to comply, as it has been the only OECD nation not to provide regular reports. Now the *Environmental Reporting Act 2015* requires a report every 6 months for one of five specified environmental areas: land, freshwater, marine, air, atmosphere and climate. The sequence will begin with a report on freshwater in mid-2016. A sixth report, to be published every 3 years, will be an overall synthesis report.

Environment Minister Nick Smith said: "The new Environmental Reporting Act will back up our clean, green brand with

authoritative and independent information on the state of our environment. It will tell us where we match up, where we don't and give regular updates so we can track long-term changes."

I was interested to see the approach being taken in New Zealand. Statistics New Zealand will manage the analysis and decide which data sets are sufficiently reliable to include. The Parliamentary Commissioner for the Environment, Dr Jan Wright, will have a role reviewing the reports. The aim is to ensure that there will be public trust in the validity of the reports, as both the Government Statistician and the Parliamentary Commissioner have guaranteed legal independence.

Apparently this issue of trust has been a problem in the past. Dr Marie Brown, senior policy analyst with New Zealand's Environmental Defence Society, said that a whole chapter of the 2007 report was "misplaced" as it "said some inconvenient things". This led to a perception that the whole exercise was political, leading to a public lack of trust in the reports.

The framework being adopted is broadly similar to what has been used in Australia for 20 years. In each area, the report will give information about the pressures on the environment, its current state and the consequences of changes in that state.

My only serious concern is one that Brown has expressed. There is no provision for a report on the state of biodiversity. Biodiversity loss is a global problem. Brown says people don't know how bad things are in New Zealand. Under this scheme, they still won't.

Ian Lowe is Emeritus Professor of science, technology and society at Griffith University.

Conduct Your Own Mouse Study



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This Little Piggy Went to Market

Gene editing promises to enable the safe use of pig organs to transplant into humans. Who could object to that?

The invention of the powerful gene-editing technique CRISPR is a game-changer for genetic engineering, making the removal or insertion of DNA sequences relatively easy and inexpensive. The key paper outlining how it works was published in 2012, but already scientists are eagerly exploiting its therapeutic and commercial potential, from modifying yeast cells to human embryos.

The latest announcement is the most exciting yet. Harvard scientists led by George Church reported in *Science* that they had removed 62 locations in the DNA of pig embryos that contained the porcine endogenous retrovirus (PERV). Technically this was a tour de force, the largest number of sites modified at the same time using CRISPR.

The danger of infection with PERV has made it impossible to consider using pig organs to replace human organs. Now it seems within reach.

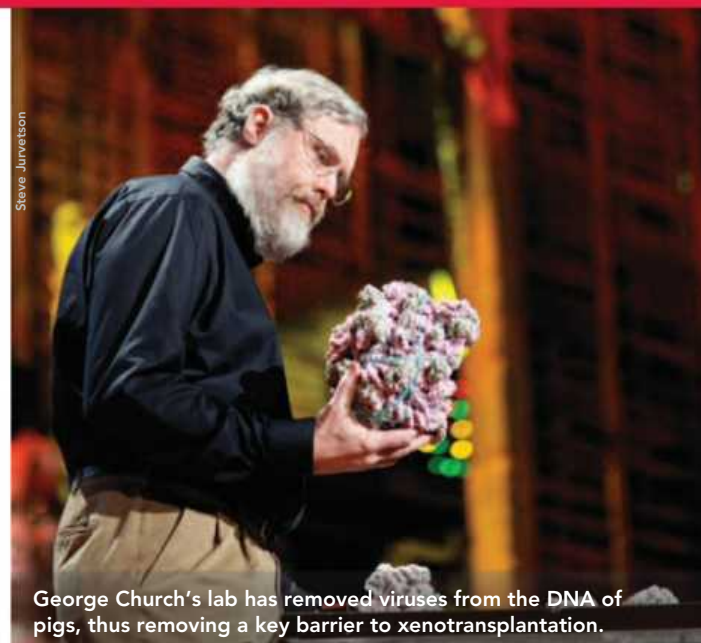
Furthermore, Church says that his team has also modified more than 20 genes that cause immune rejection or blood clotting in humans in a different set of pig embryos.

Church is nearly ready to implant the modified pig embryos into surrogate sows. "This is something I've been wanting to do for almost a decade," he told *Nature*. A Boston biotech company that he has co-founded, eGenesis, is gearing up to produce the genetically engineered pigs as cheaply as possible.

This could become a very lucrative business. Of the 120,000 people who require organ transplants every year in the US, only 30,000 receive them. Church's genetically engineered pigs, however, could supply kidneys and other organs. "This work brings us closer to a realization of a limitless supply of safe, dependable pig organs for transplant," a transplantation expert told the *New York Times*.

All of this sounds tremendously promising, but are there any ethical problems? There have been several studies of the ethics of xenotransplantation (i.e. transplants from other species) over the past 20 years or so, precisely because pigs have always seemed to be ideal sources of organs. There can be little objection as long as the risks of immune rejection and infection by pig viruses can be eliminated.

But we should expect a backlash from animal rights groups. In the past they have raised a number of objections to xenotransplants. The British Union for the Abolition of Vivisection told the Nuffield Council on Bioethics in the UK back in 1996: "The use of healthy animals as a source of 'spare parts'



George Church's lab has removed viruses from the DNA of pigs, thus removing a key barrier to xenotransplantation.

for humans represents a fundamental denial of the inherent value of those animals' lives." And a group called the Genetics Forum wrote: "The use of animals as sources of cells, tissues and organs for humans causes us much concern. It encourages the concept of animals as 'pharm' factories and reinforces the ethos that they merely exist in order to satisfy human needs."

If animal welfare groups have expressed their bitter opposition to intensive farming of pigs for bacon, they will surely object to mass production for their kidneys.

The conditions under which the pigs are kept could pose problems. They might have to be kept in isolation to keep them sterile and healthy. Pigs are social animals, so isolation and sensory deprivation could be harmful. Constant monitoring might lead to stress.

This raises an interesting problem for politicians. Faced with the dire shortage of organs, the public is bound to take a species-centric view of animal welfare: the interests of sick humans far outweigh the interests of pigs.

In recent years the notion that there is no convincing reason why a bright moral line should be drawn between humans and other animals has been steadily gaining ground. If Church's techniques are successful, the animal rights movement could be set back by decades.

Scientists should also anticipate religious objections. Some Christians believe that animals should only be used for "natural" purposes. While it may be natural to eat pigs, it may not be natural to use their organs. Jains believe that all exploitation of animal life is wrong. A Muslim group told the Nuffield Council that pigs and other prohibited animals were not acceptable as transplant sources.

In the optimistic news stories that followed the unveiling of Church's results, almost nothing was said about animal welfare and animal rights. Entrepreneurial scientists ignore this aspect at their peril.

Michael Cook is editor of *BioEdge*, an online bioethics newsletter.

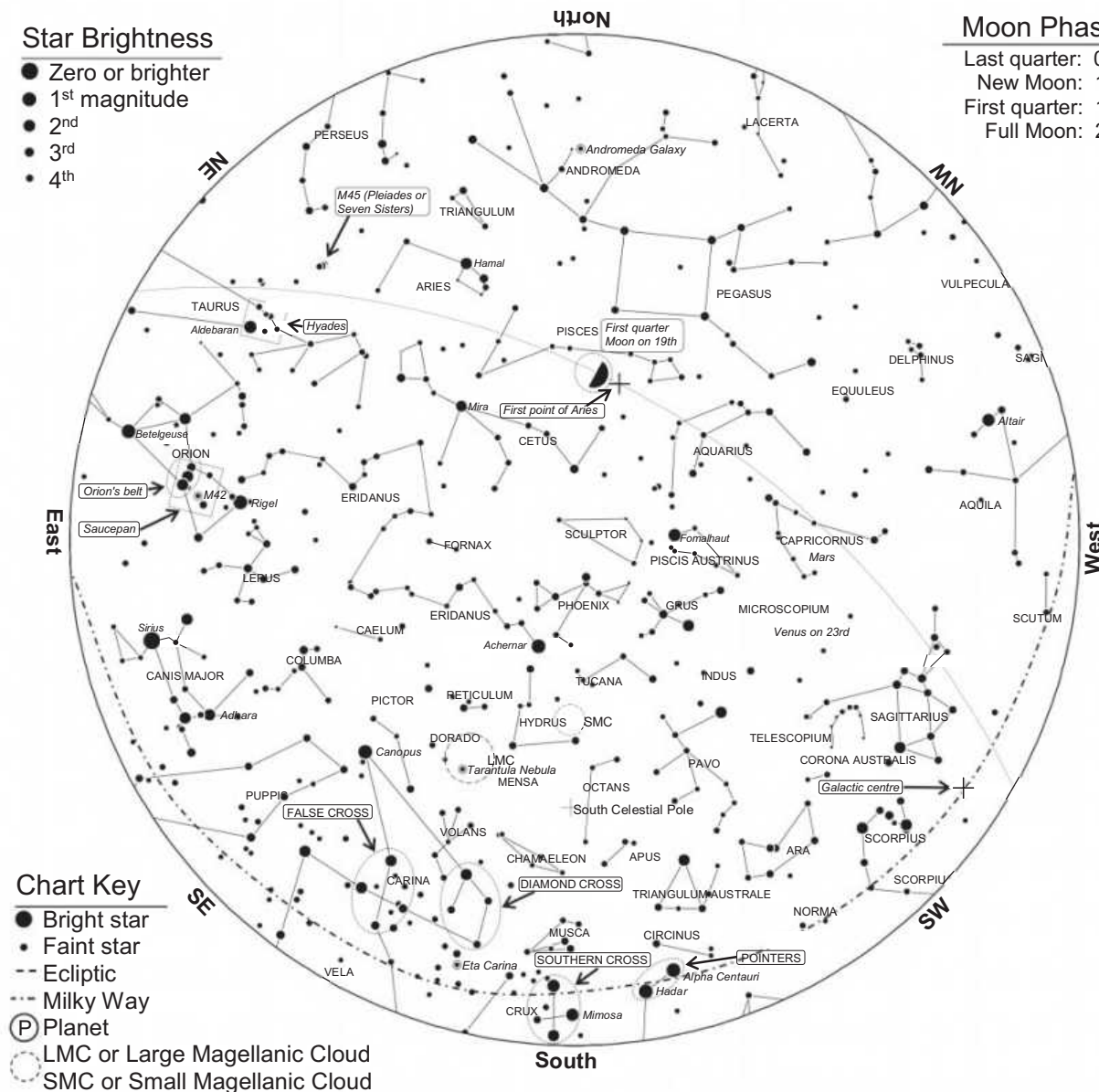
The star chart below shows the stars and constellations visible in the night sky for Sydney, Melbourne, Brisbane, Canberra, Hobart, Adelaide and Perth this month at about 7:30 pm local standard time. For Darwin and similar latitudes the chart will still apply, but some stars will be lost off the southern edge while additional stars will be visible to the north. Stars with a brightness or magnitude limit above 4.5 are shown on the chart. To use this star chart, rotate it so that the direction you are facing is shown at the bottom. The centre of the chart represents the point directly above your head (the zenith) while the outer circular edge represents the horizon.

Star Brightness

- Zero or brighter
- 1st magnitude
- 2nd
- 3rd
- 4th

Moon Phase

Last quarter: 03rd
New Moon: 11th
First quarter: 19th
Full Moon: 25th



Summer solstice occurs on the 22nd and this is the longest day of the year in the southern hemisphere, with Sydney experiencing 14 hours and 24 minutes of daylight. The best time to view the Moon using binoculars or a small telescope is a few days either side of the first quarter Moon. Crux (the Southern Cross) is just above the southern horizon making it difficult to locate, and Crux can be easily confused with the Diamond Cross, or the False Cross. So if looking for Crux, also look for the adjacent Pointer Stars. December sees the return of the summer constellations of Orion (the Hunter) and Taurus (the Bull) which can be found in the eastern part of the sky.



Sydney Observatory, with a magnificent view overlooking Sydney Harbour, is open 10am to 5pm daily – except closed Good Friday, Christmas Day and Boxing Day, and open 10am to noon on New Year's Eve. Open Monday to Saturday for night sessions (times vary depending on the season) for sky viewing through one of our telescopes (cosy planetarium session if cloudy), and 3D movies about the Universe. Bookings are essential for night programs.

For more information, check the website at www.sydneyobservatory.com.au or call (02) 9921 3485. Sydney Observatory is at 1003 Upper Fort Street, Observatory Hill, in the historic Rocks area of Sydney.

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